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WATERSHED PLANNING UNITS

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WATERSHED PLANNING UNITS
A PART OF THE COMPREHENSIVE PLAN

PREPARED FOR
THE TOWN COUNCIL, TOWN OF CARY, N. C.

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TABLE OF CONTENTS

WATERSHED PLANNING 1

Introduction 1

What is a Watershed? 3

Land Barriers 11

Description and Policy Adoption 11

WATERSHED PLANNING UNITS RESOLUTION 13

BASE DATA 16

Base Maps 16

Geological Structure 17

Stream Network 20

1) Class A-II Water 20

2) Class B Water 21

3) Class C Water 21

4) Class D Water 21

Water Quality 22

Soil Suitability 23

Urban Soil Suitability Groups 27

Group 1-a 27

Group 1-b 28

Group 2-a 29

Group 2-b 30

Group 3 31

Group 4 32

Group 5 33

Group 6 34

TABLE OF CONTENTS

Group 7 35
Group 8 36
Group 9 37
Group 10 38
Vegetation Analysis 42
Slope and Elevation Analysis 46
Flood Plains. 51
SUMMARY 51
METHODOLOGY 53
Effects of Urbanization 53
Curve Numbers 56
Direct Runoff 58
Urban Runoff 61
Urban Curve Number 61
Time of Concentration, Travel Time and Lag 65
Peak Discharge 70
IMPLEMENTATION 76
Peak Discharge for Watershed Planning Units 76
CONCLUSIONS 81
Demand vs. Response 81
BIBLIOGRAPHY 84

CHARTS AND TABLES

CHART 1 - Runoff Curve Numbers for Hydrologic Soil Cover Complexes
Soil Conversation Service 57

CHART 2 - Curve Number and Constants
Soil Conversation Service 59

CHART 3 - Runoff Depth (Q) in inches for Selected CN'S and Rainfall Amounts
Soil Conversation Service 60

CHART 4 - Runoff Curve Numbers for Selected Agricultural, Surburban, and Urban Land Use
Soil Conservation Service 63

CHART 5 - Average Velocities for Estimating Travel Time for Overland Flow
Soil Conversation Service 66

CHART 6 - CN Method for Estimating Lag
Soil Conversation Service 68

CHART 7 - Factors for Adjusting Lag when main channel is improved
Soil Conversation Service 69

CHART 8 - Factors for Adjusting Lag when impervious areas occur in the watershed
Soil Conversation Service 69

CHARTS AND TABLES

CHART 9a - Peak Rates of Discharge for Flat Slopes
SOIL CONSERVATION SERVICE 72

CHART 9b - Peak Rates of Discharge for Moderate Slopes
SOIL CONSERVATION SERVICE 73

CHART 9c - Peak Rates of Discharge for Steep Slopes
SOIL CONSERVATION SERVICE 74

CHART 10a- Factor for Adjusting Peak Discharge for a Given Future Condition CN Based on the Percentage of Impervious Area
SOIL CONSERVATION SERVICE 75

CHART 10b- Factor for Adjusting Peak Discharge for a Given Future Condition CN Based on the Percentage of Hydraulic Length Modified
SOIL CONSERVATION SERVICE 75

TABLE 1 Composite Table for a Watershed
SOIL CONSERVATION SERVICE and DEPARTMENT OF PLANNING AND DEVELOPMENT, Cary, N. C. 77

CHART II Peak Discharge in CSM per inch of Runoff vs. Time of Concentration
SOIL CONSERVATION SERVICE 79

MAPS

NEUSE RIVER WATERSHED BASIN 4

WATERSHEDS OF WAKE COUNTY 5

TOWN OF CARY AND PLANNING JURISDICTION 6

LOCATION OF JONESBORO FAULT LINE 10

SOIL MAP 25

SOIL MAP 26

VEGETATION MAP 44

VEGETATION MAP 45

ELEVATION MAP 48

ELEVATION MAP 49

SLOPE MAP 50

WATERSHED PLANNING

Introduction

Our existance is based on an immense and intricate system of systems, that can and do stimulate how we act and react. In order to implant our will upon the environment, we have acted, as history shows, with an obsession to control the elements of our environs with buildings, streets and highways situated in complete disregard for the systems of nature. The manipulation of the natural system causes retaliation by nature to reestablish its balance, which affects our perception of the elements surrounding us. Therefore, we react with additional negative attitudes towards our environment. This struggle is more evident today than at any other time because of the present technology of developing land and consuming it for our needs and pleasures.

Land use in the past has meant making the environment fit the mold that we wish without considering the consequences to the land and ourselves. Just as an example, we have determined by channelizing streams or piping them, water run-off will move off a site quickly, and have little effect on the site. What we failed to realize was the effects that took place further down the stream network; flooding, siltation, and possible losses of lives and property. Another case in point was the lack of concern of the soil type that would serve as the foundation for man made structures. Table-topping huge land areas or cutting and filling in vast volumes to achieve the desired grade took precedence over researching the most appropriate natural area to achieve a particular need. In most cases, as long as the land was not under water or too steep to climb, it was within reason to create a concrete and steel environment for our habitat. These are only two of the many areas of the environmental system that were generally neglected and abused when it came to the quality and quantity of land use.

It has only been in the last ten (10) years or so that our need for understanding environmental systems outweighed blind ventures to develop fast and furious only for economic gains. This is evident with the Environmental Protection Agency coming to the forefront; more concern for comprehensive planning through federal, state and local governments; and public awareness by means of education, publications and technical assistance.

This publication hopes to present some environmental problems and their solutions to the public's attention and at the same time, be a contribution by the Department of Planning and Development to the citizens of Cary and any who are interested in their environment; how it works and the benefits that can come from such a study. The Department also hopes that an awareness will be formed of what we are trying to achieve for the future of Cary.

The Planning Department has determined through intensive study, there are three elements that make up comprehensive planning; watersheds, population projections and economics. By investigating the structure and impact of each of these elements on our environment, we can integrate our needs with the natural systems and at the same time, minimize the effects and consequences on these balanced systems. This publication will deal basically with watershed planning, the first step to a viable relationship between man and his environment.

Watersheds are the basis for any Comprehensive Land Use Plan in that these geographic systems define how flexible we, as land users, can be in developing our land resources and maintaining a healthy environment. With the base information that a watershed provides, the other segiments of a Land Use Plan (population and economic studies) can be overlaid for needed input. From this can come essential, rational assessments of land use policies which include trans-

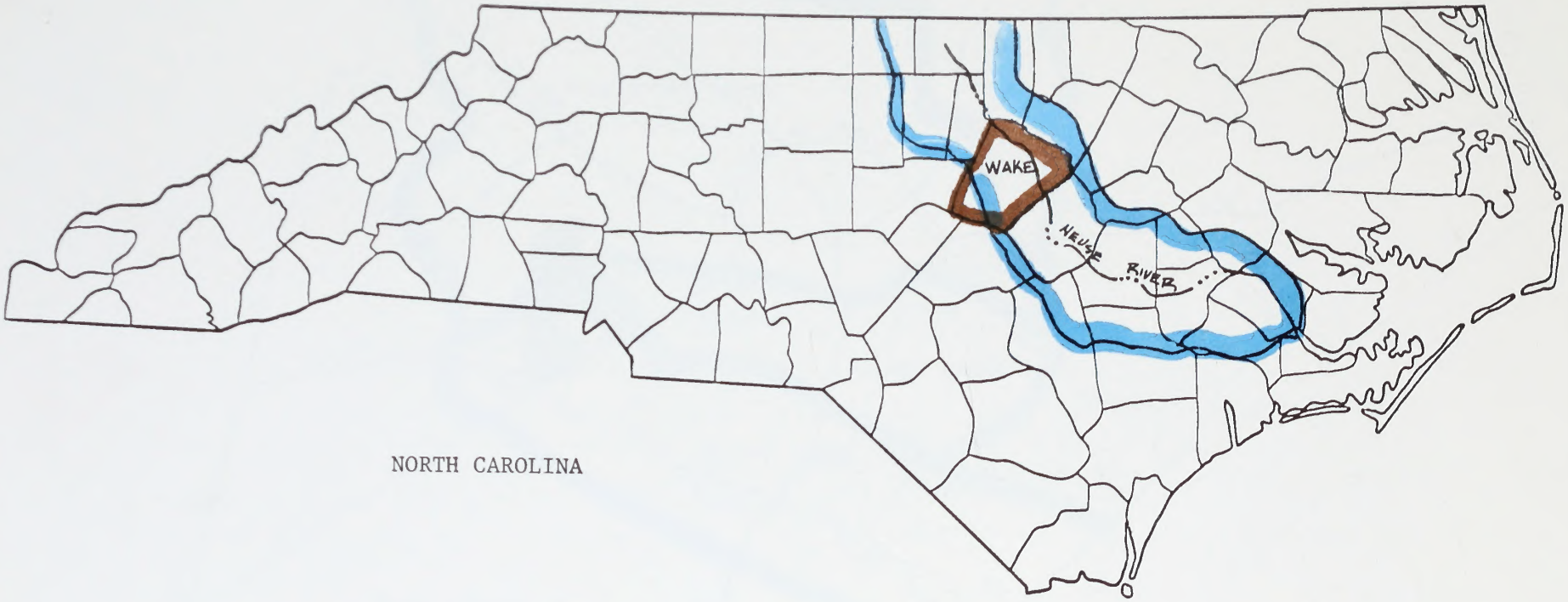
portation, water and sewer, greenways, land use management, economics and recreation, to name a few.

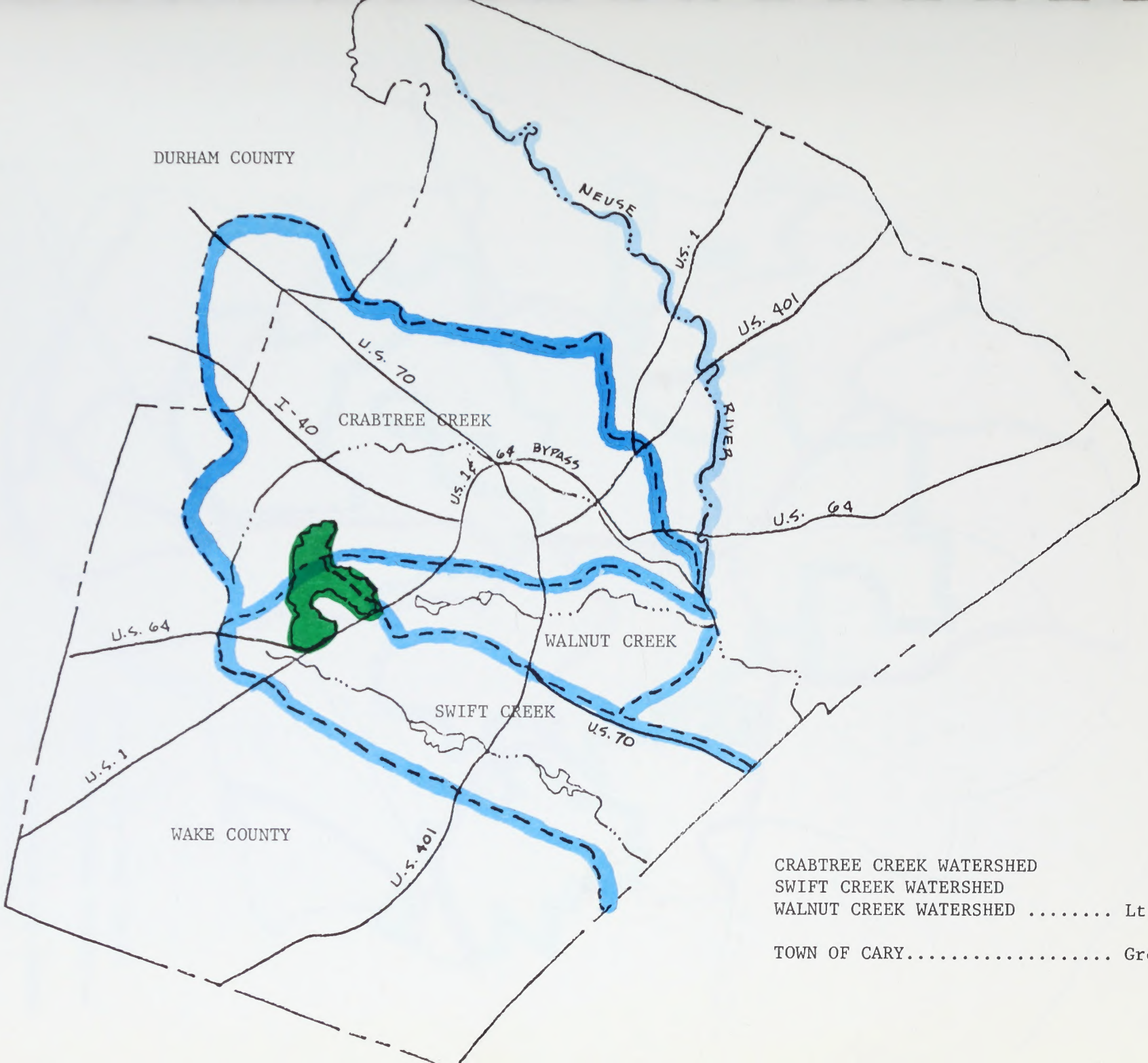
We shall deal specifically with what a watershed is, its characteristics, limitations, influence on land use planning, and the technical aspects that contribute to the development and policy making decisions of a Comprehensive Land Use Plan.

What is a watershed?

As we explore the use of watersheds in land use planning, there must be an understanding of its physical structure. A watershed, in terms of size, can range from square miles to square feet. The limit depends on the geographic location. Cary is located within the bounds of the Neuse River watershed which consists of several thousand square miles or approximately 1/10 of the State of North Carolina. At this scale, it would be almost impossible to consider such an area for land use planning for Cary's purposes. Therefore, tributaries that feed into the Neuse, which are smaller watersheds, are easier to relate to regional planning and can be studied more accurately for valuable data in the planning process. Specifically, Crabtree Creek, Swift Creek, and Walnut Creek are the three watersheds most importantly affecting Wake County. In this respect we are talking of approximately one hundred square miles. Cary is located on a crest so that from Chatham Street north is in the Crabtree Creek watershed and south is in Swift Creek and Walnut Creek watersheds. The sub-watersheds that surround Cary, of which there are twelve, average from two to four square miles in size inside the planning jurisdiction of Cary. These can be further divided into smaller watersheds of acres or square feet. On the following pages are diagrams that describe the physical boundaries of the watersheds mentioned above and the watersheds in Cary's jurisdiction.

NEUSE RIVER WATERSHED BASIN





CRABTREE CREEK WATERSHED
SWIFT CREEK WATERSHED
WALNUT CREEK WATERSHED ..... Lt. Blue

TOWN OF CARY..... Green

TOWN OF CARY AND PLANNING JURISDICTION

Green - Cary Town Limits

Gold - Watershed Boundaries

Note: Watersheds are listed numerically.

How do we determine the boundaries of a watershed? In simple terms, a ridge-line, no matter how large or small, separates one watershed from another and forces water down to the basin of the watershed by gravity to a stream or river. With a topography map of some accuracy, the ridges of a watershed can easily be determined.

The shape of a watershed is another variation to consider. In the mountain regions, most watersheds are narrow and long with mountains forming ridge-lines, while the east coast watersheds are flat and wide with small hills and crests forming the ridge-lines.

In conclusion, the two common denominators that define a watershed, physically, are the ridge-lines that form the boundaries which separate the watersheds; and water run-off within a watershed that flows to a central moving body of water like a stream or river.

Up to this point, watersheds have been defined as physical features on earth. They are also defined in technical terms that are directly related to the planning process. In these terms, watersheds are the geological areas that contribute direct run-off and base flow to a stream, which extends from the uppermost limits of a watershed ridge-line to its outlet. Depending on the size, shape, natural characteristics, and the amount of development imposed by man, the volume of runoff and peak discharge ratio between watersheds vary. Ideally, the watershed that is left in its most natural state will contribute little to any increased runoff to contend with, which if not handled properly, could cause undue flooding, sedimentation problems, and adverse water quality conditions.

This definition of a watershed will be fundamental to watershed planning and thereby contribute to the land use planning process.

The question should now be raised, what are the reasons for using a watershed

as the basis for comprehensive land use planning? The answer to this is outlined in three parts because of the huge impact that the watershed system has on the land development process.

(a) Compatibility to the planning process: When we think of "planning" in terms of development, its growth patterns and what would be most beneficial to a community, we are very definitely speaking of land, its potential and resources. Since land is structured by a series of peaks and valleys which we have previously described as watersheds, it only stands to reason that our planning process be patterned after "watershed planning units" which can be studied individually or collectively depending on the scope and data required to create the best land use planning process possible. Furthermore, the fact each watershed contributes varying degrees of water volume to the hydrologic system, it is important to monitor and analyze each watershed unit especially when development is involved.

The foundation for urbanizing a watershed unit is based on the planning and installation of sewer and water systems and transportation systems. In all cases, the watershed plays a vital part in determining their location. The first priority of installing sewer lines is to try and operate on gravity lines according to the physical structure of a watershed. Water line sizes and location relate to existing and potential development within a watershed, while transportation systems make use of the watershed ridge lines whenever possible. Therefore, since these factors are synonymous with watersheds, this gives added support to all phases of land use planning being based on watersheds. We should strive to be consistent with all phases of the Comprehensive Land Use Plan and watersheds provide this unity with natural boundaries that would not, in all probability, change physically.

(b) Geographic Differentials: Each watershed has its own characteristics and should, therefore, be considered accordingly. Based on the Cary planning area, using soils for example, Cary is divided on the west side by the Jonesboro Fault

Line as shown on the following page. The Jonesboro Fault Line is a fracture in the earth and runs in a north-south direction. This fault appeared some 200 million years ago and has since been filled with sediment deposits and has become an inactive fault in the earth's crust. East of this line, each watershed contains mostly stable soils for development except for the flood plain areas, while west of the line, the watersheds are in the Triassic Basin which represents a poor area for development. Looking at other characteristics of watersheds, there are varying percentages of slopes between one watershed and another. The slopes along with the soil type can alter the regulations for different structural forms. Vegetation, elevation, stream networks, and water runoff are all characteristics of a watershed that have to be considered in watershed planning. As a whole, each characteristic adds to the planning process that will form the base data of the Comprehensive Land Use Plan, but at the same time, each characteristic may vary when comparing one watershed basin with another. Therefore, it is logical in our development of a land use plan to research and formulate base data by watershed to minimize the embalance of natural systems due to urbanization.

(c) Systematic Format: The term "watershed" implies what is basic to natural systems. Water, no matter what form, has to be dealt with. Nature has accomplished this with the hydrology system that we learn in science. Water evaporates, forms clouds, rains on the land, and then works its way overland back to the sea where it evaporates again. The most important phase of this system and the part that has had the most consistent effect on man is water runoff over the land mass. No designated structure or landscape is considered without grading of some form to control the water runoff. This is where the problems begin, when the organized natural system becomes intangled in man's superficial systems. The idea is to be

LOCATION OF JONESBORO FAULT LINE

aware of both natural and man-made systems and place them in formal harmony with each other. By understanding and utilizing watershed planning units as part of the planning process, we can take a basic step toward a systematic formula that means environmental survival for man and nature.

Land Barriers

As was presented earlier, the boundaries of a watershed are the ridge-lines. These form a natural barrier to study each watershed under limited natural controls that would have to be implemented otherwise. We are sure of the stream flow and water runoff as to direction and are able to monitor more accurately the volume of runoff and peak discharge of a stream because of the natural barriers. We are also provided with a defined area in which to concentrate land use planning.

This brings us to the initial step of developing watershed planning units as part of the comprehensive plan. From this point, all studies will be oriented directly or indirectly to Cary and its Comprehensive Land Use Plan.

Description and Policy Adoption

The Planning Department felt it was imperative to establish the boundaries of the watershed planning units in such a manner that would easily be interpreted by the Town Council and Cary's citizens. These descriptions are basically general in nature and relate to existing features, where available, such as roads and railroad tracks. After the technical studies have been completed for each watershed unit, a more precise boundary will be surveyed and established as a permanent dividing line between the watershed planning units.

The following pages are devoted to the resolution presented to the Town Council and adopted as "Watershed Planning Units" within the planning jurisidiction of Cary. The resolution includes a description of each of the thirteen watersheds and the approximate acres. The watershed planning units in some cases, extends

beyond Cary's one mile extraterritorial limits; this was done to account for the extension of the jurisdiction line to two miles in the future. As Cary expands its growth, the watershed technical studies will have been completed and will simplify implementing the development policies for a particular watershed that was within Cary's jurisdiction previous to the two mile extension. Thus, the watershed planning units provide the centroid for proper assessment of the natural resources in and around Cary and provide legal arguments for Cary to occupy and urbanize in an orderly and responsible manner that is consistent with the character of the land and the desired community environment. For this reason, the Town Council, on March 27, 1975, adopted a resolution to establish "Watershed Planning Units" and directed the Planning and Engineering Departments to make the necessary technical studies of each planning unit and recommend development policies and ordinances as a result of such studies. This is now under way by both Departments.

A RESOLUTION TO ADOPT WATERSHED DRAINAGE AREAS LOCATED WITHIN THE TERRITORIAL AND EXTRA-TERRITORIAL JURISDICTION OF THE TOWN OF CARY AS PLANNING UNITS

WHEREAS, it is the expressed intent of the Town Council of Cary that the territorial and extraterritorial jurisdiction of the Town be developed for human settlement, occupation and urban utilization in an orderly and responsible manner for the purpose of promoting health, safety, morals and the general welfare of the community and consistent with the desire and legitimate right and need for a quality environment and life of the community and its citizens, and

WHEREAS, it is the responsibility and duty of the Cary Planning and Zoning Board and the Department of Planning and Development to make a careful study of the resources, possibilities and needs of the Town, particularly with respect to the conditions which may be injurious to the public welfare or otherwise injurious, and make plans for the development of the territorial and extraterritorial jurisdiction of the Town of Cary, pursuant to G.S. 160A-360(b) and G.S. 160A-361 of General Statutes of North Carolina, and

WHEREAS, past development in combination with natural resources and natural phenomena have produced occurences of hazard to the public health, safety and general welfare, as well as occurrences of injurious conflict, blight and deterioration to property of citizens, to the lands and landscape of the environs and to the community, and

WHEREAS, it is the intent that development of the Town should not unduly sacrifice the natural resources and amenities of the environs, and that the orderly growth of the Town be conducted with the best available procedures for the mapping, assessment, planning and engineering of the territorial and extraterritorial jurisdiction of the Town, and that such planning and engineering be consistent with and conserve to the greatest extent wherever proper and possible the natural resources, beauty and amenities of the environment;

NOW, THEREFORE, BE IT RESOLVED by the Town Council of the Town of Cary:
(1) The below described areas are hereby established as Watershed Planning Units within the environs of and surrounding the Town, and the Watershed Planning Units shall be the basic geographical planning areas for the Town:

Location of Watershed Planning Units	Land Area
A. Reedy Creek Planning Unit - occupies those lands draining into Reedy Creek and its tributaries above its confluence with Crabtree Creek. The unit is generally bounded on the east by Trinity Road, on the south by Southern Railway lines, on the west by the Old Cary State Park Road and on the north the lower reaches cross William B. Umstead State Park.	3,080 acres
B. Black Creek Planning Unit - occupies those lands draining into Black Creek and its tributaries above its confluence into Crabtree Creek. The unit is generally bounded on the east by the Old Cary State Park Road, on the west by County Road 1653, or as shown on maps of the Cary Planning and Engineering Department.	2,494 acres

C. CCT-6 Planning Unit - 1,087 acres
occupies those lands draining into this unnamed stream (as shown on maps of the Town of Cary) which is a tributary of Crabtree Creek downstream from Coles Branch and above Black Creek.

D. CCT-5 Planning Unit - 274 acres
occupies those lands draining into this unnamed stream (as shown on maps of the Town of Cary) which is a tributary of Crabtree Creek. The unit is generally bounded by U.S. 54 near Morrisville and CCT-6 Planning Unit.

E. Coles Branch Planning Unit - 1,808 acres
occupies those lands draining into Coles Branch and its tributaries above its confluence into Crabtree Creek. The unit is generally bounded on the north by U.S. 54 and as shown on maps of the Town of Cary.

F. Upper Crabtree Creek Planning Unit - 2,896 acres
occupies those lands draining into this unnamed stream and tributary of Crabtree Creek above the confluence of Turkey Creek. The unit is generally bounded on the southeast by County Road 1011 (as shown on maps of the Town of Cary).

G. Upper Swift Creek Planning Unit - 3,556 acres
occupies those lands draining into Swift Creek above the confluence of SCT-7 stream. The unit is generally bounded on the west by County Road 1011 in the Town of Apex (as shown on maps of the Town of Cary).

H. SCT-8 Planning Unit - 1,416 acres
occupies those lands draining into this unnamed stream (as shown on maps of the Town of Cary) and tributary of Swift Creek. The unit is generally bounded on the south by County Road 1379 and 1300.

I. SCT-7 Planning Unit - 3,391 acres
occupies those lands draining this unnamed stream and tributary of Swift Creek (as shown on maps of the Town of Cary). The unit is generally bounded on the northwest by the Crabtree Basin along County Road 1011 and on the south the mainstem stream crosses through the MacGregor Downs Lake.

J. SCT-6 Planning Unit - 968 acres
occupies those lands draining into this unnamed stream (as shown on maps of the Town of Cary) and tributary of Swift Creek. The unit is generally bounded on the west by County Road 1300 and on the east by SCT-5 Planning Unit.

K. SCT-5 Planning Unit - 2,455 acres
occupies those lands draining into this unnamed stream and tributary of Swift Creek (as shown on maps of Town of Cary). The unit is generally bounded on the north by the Upper Walnut Creek Unit.

L. SCT-4 Planning Unit - 1,147 acres
occupies those lands draining into this unnamed stream (as shown on maps of the Town of Cary) and tributary of Swift Creek. The unit is generally bounded on the northeast by the Cary Macedonia Road and on the east by County Road 1152.

M. Upper Walnut Creek Planning Unit - 3,594 acres
occupies those lands draining into Walnut Creek and its tributaries above its confluence onto Lake Johnson. The unit is generally bounded on the north by Southern Railway lines and on the south by the Cary Macedonia Road.

(2) The Town Department of Planning and Development and the Engineering Department are hereby directed to make studies of each Watershed Planning Unit consistent with the intent of this resolution and with special attention to:

a. objectives to be sought in the development of each Watershed Planning Unit, including development guidelines and restrictions for each basin,
b. suitability assessments of various land use types, densities and locations, as well as, suitability assessments for greenway, openspace, schools, future development densities, and park lands,
c. assessments of necessary transportation, sewer and water requirements and a plan for implementation.
d. recommended policies, ordinances, administrative procedures and other means for the implementation of the Floodplain, Soil Erosion and Sedimentation Control and Dedication of Open Space Ordinances,
e. recommended urban runoff controls for each basin,
f. assessments of all physical land characteristics in each basin, including, but not limited to, soils slope, geology, stream flow, water quality and other pertinent facts necessary for the assessment,
g. other pertinent facts necessary for responsive public policy determinations by the Town Council consistent with this resolution.

Adopted this 27th day of March, 1975.

BASE DATA

Base Maps

Through the guidance of the Engineering and Planning Departments, aerial photographs were taken of Cary and its extraterritorial jurisdiction which subsequently produced topographic maps at two foot contour intervals. The topographic assessment consists of thirty-nine (39) maps and will be the base maps for all studies relating to the watershed planning units and their characteristics.

Adding to the information that the aerial photographs and topographic maps provide; reconnaissance of the watersheds were made to study the stream networks and geological structures.

The Planning Department worked to assemble as much vital information as was possible to insure a thorough and complete land use assessment aimed at providing the most effective environment for Cary. Much of the base information was provided by the Soil Conservation Service and the Department of Natural and Economic Resources. It was up to the Planning Department to assemble, analyze and determine the best use of the data. It was also necessary to determine and map the basic natural systems of the watershed planning units before an attempt could be made to outline any development policies. These natural systems were interpreted as natural land characteristics which included geological structures, stream networks, soil groups, vegetation cover, elevation and slope studies, floodplain areas, and water quality. With this data, the Planning Department can begin analyzing the information and tieing it together into useable policies for various land use types, densities and locations, as well as suitability for recreation use, schools, open-space, transportation, and sewer and water.

Each land characteristic of the watershed unit will be discussed in the following pages giving as much technical information as possible so there is a good understanding of Cary's land resources.

Geological Structure

Previously in this publication, reference was made to the Jonesboro Fault line. This is a good point of entry to study the geology in and around Cary. This fault serves as a divider between the Triassic Basin on the west and the christaline rocks on the east side that are more suitable for land development. The Triassic Basin is from five to twenty miles wide and runs in a north-northeast and south-southwest direction. This basin is known for its poor soils and low water availability, and rightly so, because of the rock structure. First, several terms will help to understand the Triassic Basin problems.

Aquifer is an earth material having uniform water bearing characteristics. The Triassic Basin acquifers generally receive and transmit water poorly.

Impervious means that water cannot penetrate, and impervious rocks cause heavy rains to runoff quickly and at a high volume over a short period of time.

Porosity is the percent of pores or pore space in rock. This means the amount of water that a rock formation can hold is dependent on the bumber of pores in its structure.

Permeability is the capacity of rock to allow water to move through its pores which determines the yields of wells within a geological unit.

The Triassic Basin consists of maroon colored clays, silts and sands that have been compacted into fairly hard shales, siltstones and sandstones. The abundance of clay sized particles compressed together has greatly reduced pore space and left the rock nearly impermeable. Fractures within the rock are often sealed with clay particles when water enters the fractures causing the rocks to remain essentially impermeable. This results in less water entering the ground-water reservoirs and little or no water entering wells. Average figures indicate the ability to produce water is less than 1/10 of a gallon of water per foot of well.

Under these conditions, a developer or home owner may be hard pressed to produce a reliable quantity of water to carry on daily needs if municipal water lines were not available. This also means that waste disposal is a problem. To complicate this situation even more, we find that clay content of the rock structure often causes a severe shrink-swell potential causing fractures in masonry walls and foundations. Clay and shale have a high ability to swell when saturated and shrink when water evaporates and the clay dries. With the sedimentary rock structure in its present state and water having no place to go, this shrink-swell process occurs at a high intensity which can cause damage to building structures and roads when restrictive development measures are not taken.

The Triassic Basin is not an area that should be bypassed for any further urbanization despite its problems. It is not completely void of available water or potential development sites. The basin once had many faults within its rock structure. The sedimentary deposits in the basin are well fractured in some areas due to the injection of diabase dikes. These dikes provide the most abundant water areas in the Triassic Basin. Locating these could be difficult, but with the aid of the Department of Natural and Economic Resources' publication entitled "Region J Geology: A guide for North Carolina Mineral Resources Development and Land Use Planning", locating these dikes for future water needs is a much easier task. Probably the most pressing question is how can development utilize the Triassic Basin? Since Cary's jurisdiction line extends into this basin, it is most important for the Town Council and the developer to understand the development consequences from an economic and land use standpoint. The Triassic Basin can be urbanized, but the development requirements will have to be more restrictive in nature and more rigidly enforced. Development has taken place, but the ratio of urban use to existing rural land is very slight. The

Research Triangle is the single largest development in the Triassic Basin in Cary's immediate area. Due to the large buffers, rip-rapping and modified foundations for buildings, the Triangle has been able to lend itself to its environment and surrounding land characteristics without too many problems. As Cary grows and expands its urban dimensions, the problems that arise will be more complex and injurious to the environment in the Triassic Basin. Therefore, Cary must be prepared to insure proper development criteria to a larger extent than is now required on the east side of the Jonesboro Fault.

The east side of the Jonesboro Fault has more useable land, percentage wise within Cary's jurisdiction even though there are some areas that would have to be considered under strict development requirements. The rock structure is more suited, than in the Triassic Basin, for urbanization with minimal problems if proper land use measures are imposed. Geology wise, this part of Cary's jurisdiction is made up of complex metamorphic rocks. These are extensive areas of metavolcanics and gneiss which produce usable quantities of water. Even though the aquifer is not outstanding in the Triangle J Region as a whole, of which Cary is a part, there exist a much higher availability of water in chrystaline rocks than in the Triassic Basin. Water moves freely through the rock structures and allows a good base flow leading to the streams in the area. Presently, Cary's growth has been concentrated east of the Jonesboro Fault line without too many problems. We cannot expect the same results as Cary extends west.

In assessing the geological structure influencing Cary, we can more readily understand and anticipate the problems of water availability as well as the need and most appropriate use of sewer and water in the unstable geological areas. The geological survey is literally the foundation that contributes to the evaluation and analysis of the remaining natural systems of the Watershed Planning Unit. For example. we already know that a watershed on the west side of Cary will

suffer more, development wise, because of the lack of well water and the shrink-swell capability as compared to a watershed east of Cary. Here, water is available at a higher rate and the geological foundation for building structures has greater stability. Technically, we could break down the geology in greater detail, but for the purpose of Cary's Land Use Study, a general status is all that concerns the Planning Department at this point. If there is additional interest, more detail of the rock structures and mineral resources can be obtained by contacting the Cary Planning Department or The Department of Natural and Economic Resources.

Stream Network

It is important to understand and define the order of streams and determine their relationship to the land use planning process. Each Watershed Planning Unit that Cary adopted was considered for its stream network and benefit to the community as well as the entire region. To protect the different levels of water use for our needs, and to see that the proper use of land within the varied stream networks is maintained, the Planning Department used the present classifications for certain streams and tributaries in accordance with the North Carolina Environmental Management Commission ratings of water use.

This classification is divided into four (4) types. All streams were classified which the Commission determined as major contributors to the water system. These classes are as follows:

Class A-11 Waters: rated to be maintained as waters if subject to approved treatment equal to coagulation, sedimentation, filtration and disinfection with additional treatment, if necessary, to remove naturally present impurities, that will meet the "Public Health Service Drinking Water Standards", and will be considered safe for drinking, culinary or food processing

purposes. Also, suitable for other uses requiring waters of lower quality.

Class B Waters: rated to be maintained as waters under proper sanitary supervision by the controlling health authorities that will meet accepted standards of water quality for outdoor bathing places and will be considered safe and satisfactory for bathing purposes. Also, suitable for other uses requiring waters of lower quality.

Class C Waters: rated to be maintained as water that will be suitable for fish and wildlife proagation, boating and wading. Also, suitable for other uses requiring waters of lower quality.

Class D Waters: rated to be maintained such that the waters, without treatment and except for natural impurities which may be present therein, will be suitable for agricultural uses and will permit fish survival. The waters will also be usable after special treatment by the user as may be needed under each particular circumstance for industrial purposes, including cooling and process waters.

The Planning Department has incorporated the stream classifications within Cary's jurisdiction on a large base map for each Watershed Planning Unit. This will be a factor in determining where water runoff will be detained, if any, due to the rate of development.

The reasons for the Planning Department's concern for this study of the natural stream system is twofold. First, the water that flows within Cary's community is part of the water system for drinking as well as a source for wells in this area. If we cannot help maintain some form of quality in the water, the expense to clean the water would be a great economic factor. In the same light, use of the water for recreation and similar desires would be limited because of the

quality of water. Second, the ability to channelize the flow of water runoff to contain streams and retention ponds will enable better control of the volume of runoff and peak discharge and will further help determine the design capacity needed for retention basins.

Water Quality

In conjunction to the stream network is water quality which must be maintained in order to have a good water resource. Through the 208 Water Quality Program with Region "J" there is a study being conducted to set goals and criteria for water quality management. Great concern is in "point" and "non-point" sources of pollution. "Point" sources of pollution are those created by the disposal of waste water from known outlets. A prime example of this is the industrial waste water that is poured into a river. "Non-point" pollution is mainly the result of urbanization and the runoff from rain storms. This includes the gas and oil stains being washed off a parking lot or the exposed land that silts the streams and enhances sedimentation problems. Basically, for Cary, its major concern at present are non-point sources of pollution. There are no major industrial uses that contribute any amount of pollution to our water resources.

It is one thing to locate these sources of pollution, but another to devise systems and design methods to control the water pollution. The Cary Planning Department feels very strongly that in order to maintain and improve the water quality there has to be some type of controls imposed on the volume of runoff and peak rate of discharge first; then measures to specifically maintain a certain water quality could be enacted.

The idea is to retain water runoff and release it in a manner comparable to as natural a condition as possible in relation to the influence of densities and type of urbanization. This methodology will have a positive impact on the

non-point sources of water pollution as well as add to the amenities of the community and aid in controlling down stream flooding. Where "point" source pollution is concerned, Direct Control Ordinances will have to be implemented to treat, or in some way, contain any adverse waste water which would otherwise be dumped into our stream networks.

As a matter of information, Cary has good water quality; the ground water in this area has iron particles which are the most objectionable. It is the view of the Town Council and the Planning Department that goals should be established for maintaining our present water quality as a part of the Comprehensive Land Use Plan to assist in giving a more positive outlook towards Cary's environment and community appearance.

Soil Suitability

All the natural characteristics of the Watershed Planning Units that are being studies will aid tremendously in finalizing a Comprehensive Land Use Plan, but none will have more immediate impact than the soils and their characteristics when it comes to the versatility of development, and economics. Wake County is unique because there are more soil groups here than anywhere else in the State of North Carolina. This, in itself, complicates matters for both the developer, the citizen, and the governing bodies who are trying to solidify a common medium for man and environment.

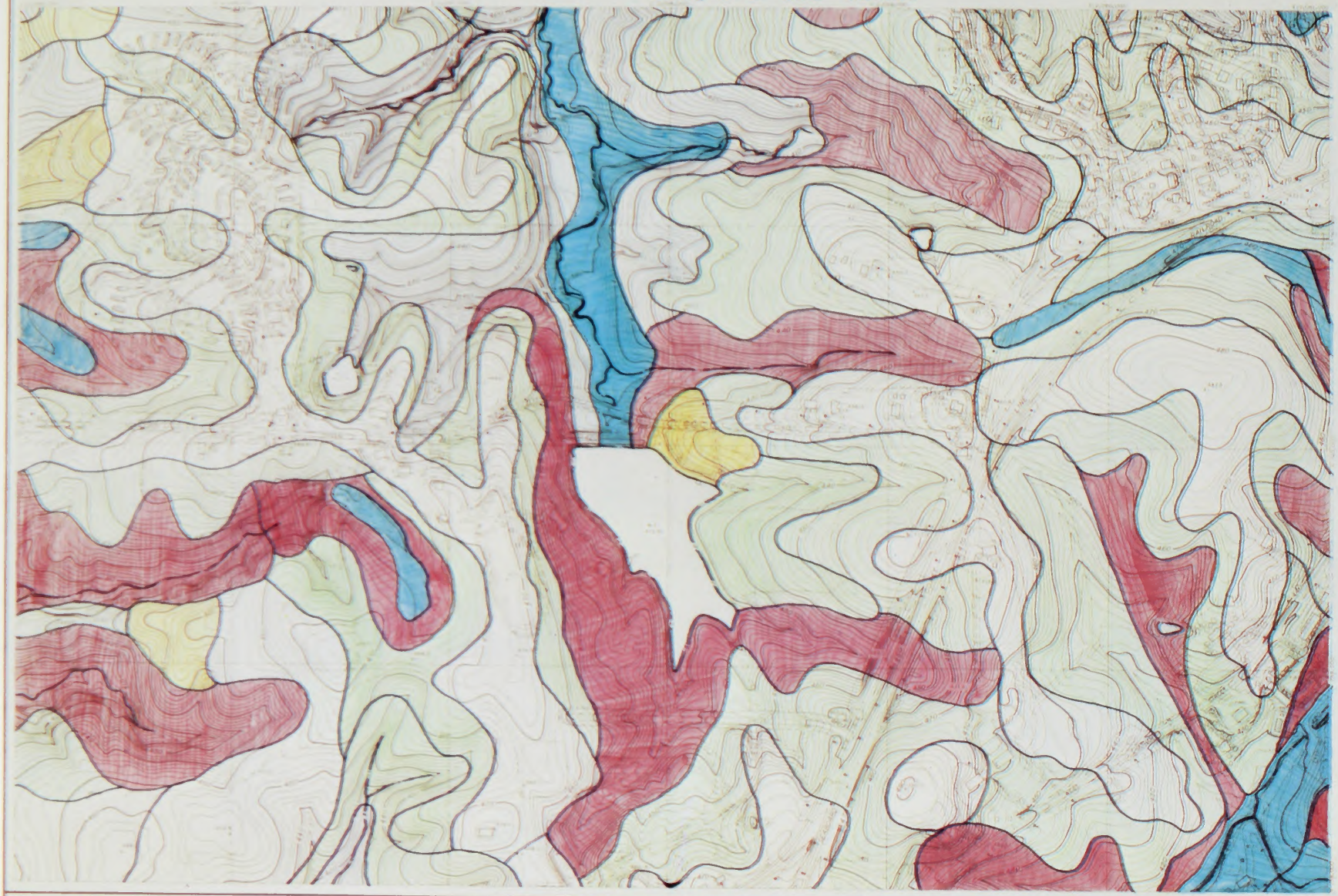
There are several elements that combine to form soils, parent material (chemical and mineralogical composition), climate, plant and animal life, relief (geological rock structure), and time. The characteristics of a soil is dependent on a combination of these elements at a particular location and the natural efforts exerted. It is not unusual to have one or two of these elements predominate in the process of developing soil types. Due to the wide variation of soil types,

they are classified so that the specific characteristics can be easily recognized and to indicate the significance each soil portrays in the natural environment. Where the greatest concern rest, is the relation of soils to urbanization; by understanding the behavior of soils and their reactions when they are manipulated, there is a greater insurance that competent development will take place.

Wake County, between 1956 and 1965, was surveyed, classified and mapped. This soil survey was published in 1970 by the Wake County Soil Conservation Service and was one of the major references in the Planning Departments development of a Soils Base Map. Since this publication, Wake County has classified soils as "Urban Soil Suitability Groups". The Planning Department has adopted this classification as a means to simplify and update the soil suitability for development guidelines. All soil types with similar characteristics were classified under the same category and color coded. What this accomplished was to reduce the number of soil types from some one-hundred and fifty, to twelve (12) major soil groups. They range from Group 1-a being the most suitable for urbanization, to group 10, which are flood plain and alluvial soils.

Using the two (2) foot contour topographic maps, the soil types were superimposed and colored according to the "urban soil suitability group". In all, there are thirty-nine (39) soil maps. On the following pages, several of the soil base maps and the twelve soil groups have been included in this publication to give an indication of the visual and technical data available. Each soil group is classified by a hydraulic soil group letter. This will be explained later in the publication.

CARY, N. C. AND VICINITY



LEGEND

CARY

SOIL MAP

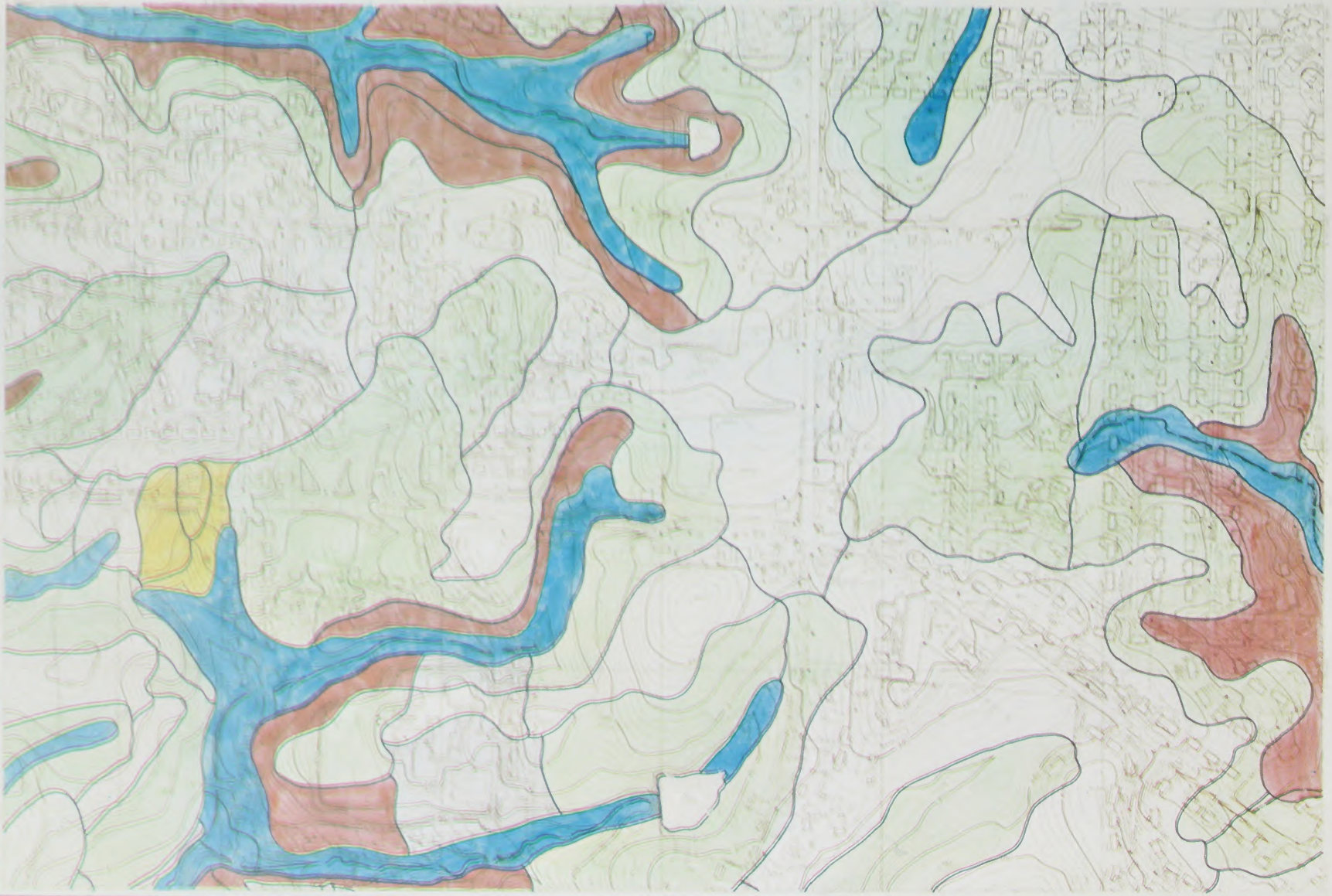
27	28	29
22	23	24
17	18	19

TOWN OF

CARY

NORTH CAROLINA

CARY, N. C. AND VICINITY



LEGEND

CARY

SOIL MAP

TOWN OF

CARY

NORTH CAROLINA

URBAN SUITABILITY
GROUP 1-a
HYDROLOGY SOIL GROUP - B

Color: Flesh

SOIL NAME	SOIL SYMBOL	
Appling (B)	AgB	1/
	AgB2	1/
	ApB	
	ApB2	
	AsB	
	AsB2	
Cecil* (B)	CeB	
	CeB2	
	CgB	1/
	CgB2	1/
	ClB3	3/
Durham (B)	DuB	2/
	DuB2	
Faceville** (B)	FaB	
	FaB2	
Georgeville (B)	GeB	3/
	GeB2	3/
Granville (B)	GrB	
	GrB2	
Herndon (B)	HrB	3/
	HrB2	3/
Lloyd (B)	LdB2	3/
Madison* (B)	MdB2	
Mayodan (B)	MfB	
	MfB2	
	MgB	1/
	MgB2	1/
	MyB	3/
	MyB2	3/
Wedowee*** (D)	WmB	
	WmB2	

* underlain by micaceous clays
** also in group lb
*** local rock ledges at 4 feet
1/ gravel on surface
2/ thick sandy surface layer
3/ loamy or silty surface layer

Group 1-a Deep well drained undulating soils well suited for most urban uses. Moderate to moderately severe erosion potential with extensive grading.

URBAN SUITABILITY
GROUP 1-b
HYDROLOGY SOIL GROUP - B

Color: **Sand**

SOIL NAME	SOIL SYMBOL
Faceville* (B)	FaB
	FaB2
Norfolk** (B)	NoA
	NoB
	NoB2
Orangeburg** (B)	OrB
	OrB2

* Also in group 1-a

** very sandy surface layers

URBAN SUITABILITY
GROUP 2-a
HYDROLOGY SOIL GROUP - B

Color: True Green

SOIL NAME	SOIL SYMBOL
Appling (B)	AgC 1/
	AgC2 1/
	ApC
	ApC2
	AsC
	AsC2
Cecil* (B)	CeC
	CeC2
	CgC 1/
	CgC2 1/
	ClC3 3/
Durham (B)	DuC 2/
	DuC2 2/
Faceville** (B)	FaC2
Georgeville (B)	GeC 3/
	GeC2 3/
Granville (B)	GrC
	GrC2
Herndon (B)	HrC 3/
	HrC2 3/
Lloyd (B)	LdC2 3/
Madison* (B)	MdC2
Mayodan (B)	MfC
	MfC2
	MgC 1/
	MgC2 1/
	MyC 3/
	MyC2 3/
Wedowee*** (D)	WmC
	WmC2

* Underlain by micaceous clays
** also in group 1b
*** local rock ledges at 4 feet
1/ gravel in surface
2/ thick sandy surface layer
3/ loamy surface layer

Group 2-a Deep, well drained strongly undulating soils. Extensive grading required for some urban uses. Severe erosion potential with extensive grading. Intensive soil and water management facilities required during and after construction to protect site and downstream interests. Best suited to those urban uses not requiring extensive grading.

URBAN SUITABILITY
GROUP 2-b
HYDROLOGY SOIL GROUP - B

Color: Light Green

SOIL NAME	SOIL SYMBOL
Faceville* (B)	FaC2
Norfolk** (B)	NoC
	NoC2
Orangeburg** (B)	OrC2

* also in group 2-a

** very sandy surface layers

URBAN SUITABILITY
GROUP 3
HYDROLOGY SOIL GROUP - B

Color: Crimson

SOIL NAME	SOIL SYMBOL
Appling (B)	ApD
Cecil* (B)	CeD
Georgeville (B)	GeD2 1/
Granville (B)	GrD
Herndon (B)	HrD2 1/
Lloyd (B)	LdD2 1/
Madison* (B)	MdD2
Mayodan (B)	MfD2
	MyD 1/
Wedowee** (D)	WmD2

* underlain with micaceous clays

** local rock ledges at 4 feet

1/ loamy surface layers

Group 3 Deep, well drained soils located on steep slopes. Extensive grading required for most urban uses. Resulting exposed rock areas and steep embankments difficult to stabilize. Very severe erosion potential with extensive grading. Very intensive soil erosion and water management facilities required during and after construction to protect site and downstream interests. Not suited for those urban uses requiring extensive grading.

URBAN SUITABILITY
GROUP 4
HYDROLOGY SOIL GROUP - C

Color: Yellow Achre

SOIL NAME	SOIL SYMBOL
Creedmoor (C)	CrB
	CrB2
	CtB
Helena (C)	HeB
	HeB2
White Store* (D)	WsB
	WsB2
	WTB 1/

very sticky and very plastic subsoils

thin loamy surface layer

URBAN SUITABILITY
GROUP 5
HYDROLOGY SOIL GROUP - C

Color: Brown

SOIL NAME	SOIL SYMBOL
Creedmoor (C)	CrC
	CrC2
	CtC 1/
Enon (C)	EnB
	EnB2
	EnC
	EnC2
Helena (C)	HeC
	HeC2
Vance (C)	VaB
	VaB2
	VaC2
White Store* (D)	WsC
	WsC2

* very sticky and very plastic subsoils

1/ loamy surface layer

URBAN SUITABILITY
GROUP 6
HYDROLOGY SOIL GROUP - A

Color: Yellow

SOIL NAME	SOIL SYMBOL
Wagram (A)	WaA
	WaB
Wagram-Troup (A)	WgA
	WaC

URBAN SUITABILITY
GROUP 7
HYDROLOGY SOIL GROUP - C

Color: Dark Green

SOIL NAME	SOIL SYMBOL
Goldsboro (C)	Go
Lynchburg (B/D)	Ly 1/
Plummer* (B/D)	Ps 2/
Rains (B/D)	Ra 2/

* very deep loose sandy soils

1/ Water table near surface during wet periods

2/ Water table on surface during wet periods

URBAN SUITABILITY
GROUP 8
HYDROLOGY SOIL GROUP - C

Color: Lavender

SOIL NAME	SOIL SYMBOL
Louisburg (B)	LoB
Louisburg-Wedowee* (B/D)	LwB
	LwB2
	LoC
	LwC
	LwC2
Pinkston (B)	PKC
Wake** (D)	WKC
Wilkes*** (C)	WwC

* Wedowee soils are at least 4 feet to hard rock

** hard rock at about 15 inches

*** Wilkes soils have thin sticky and plastic subsoils

URBAN SUITABILITY
GROUP 9
HYDROLOGY SOIL GROUP - C

Color: Gray

SOIL NAME	SOIL SYMBOL	
Cecil (B)	CeE	
	CeF	
	ClE3	
Creedmoor (C)	CrE	
Enon (C)	EnD2	1/
Helena (C)	HeD	1/
Herndon (B)	HrE	
Louisburg (B)	LoD	1/
Madison (B)	MdE2	
Mayodan (B)	MfE	
Pinkston (B)	PkF	
Wake (D)	WkE	
Wedowee (D)	WmE	
	WmF	
White Store (D)	WsE	
	WvD3	1/
Wilkes (C)	WwE	
	WwF	
	WxE	2/

1/ average slopes less than 15%

2/ many stony outcrops

Group 9 Soils with thin surfaces located on steep slopes. Suited to woodland, wildlife and recreation. Not suited for most urban uses.

URBAN SUITABILITY
GROUP 10
HYDROLOGY SOIL GROUP - C

Color: Blue

SOIL NAME	SOIL SYMBOL*	
Altavista (C)	AfA	1/
Augusta (C)	Au	
Buncombe (A)	Bu	
Chewacla (C)	Cm	
Colfax (C)	Cn	2/
Congaree (B)	Co	3/
Congaree (B)	Cp	3/
Mantachie (C)	Me	
Roanoke (D)	Ro	
Wahee (D)	Wh	
Wehadkee (D)	Wn	
Wehadkee and Bibb (B/D)	Wo	
Worsham (D)	Wy	
---	--	
Swamp (D)	Sw	4/

1/ floods less frequent than group average

2/ local flooding or ponding

3/ better drained than group average

4/ water above surface most of year

* all soils have severe flood hazard if contiguous to drainageways or other soils in group

Studying soils will give the Planning Department a good insight into the available, useable land for Cary's needs. No soil type, except flood plains, will be restricted from supporting some type of development, the only difference will be in the type of construction and the amount of development that a particular soil group will be capable of supporting.

The economic situation for the Town which relates directly to the taxpayer will be influenced by the Town Council's decisions on where development will be allowed and the policies and procedures involved. Too many times it has been proven that a municipality would allow extensive growth for its community anticipating large revenue, then have the life expectancy of streets, building foundations, water and sewer lines and erosion control measures cut short of their normal use because there were no pre-investigations made of the soil conditions. With Cary's location dominated by such a variety of soils, it is to Cary's advantage economically, as well as environmentally, to educate itself and understand the nature of soils.

Technically, soil properties influence the process of direct runoff from rainfall. Different soils react differently to storm water, depending on the infiltration rate, which is the rate that water enters the soil at the surface and is controlled by surface conditions, and transmission rate, which is the rate water moves in the soil and is controlled by the soil horizons. We can analyze the amount of water soils can hold and when they reach their saturation point. Once a soil type reaches its saturation point, this is when direct runoff becomes most apparent and can have the greatest influence in flooding and erosion problems. Soils having a high infiltration rate (sand or gravel) have a low runoff potential, and soils having a low infiltration rate (clay) have a high runoff potential. For this reason, urbanizing on soils with high infiltration capabilities will increase the volume of runoff more than urbanizing on soils with low infiltration capabilities.

Two phrases have been mentioned which need clarification in relation to water runoff. Surface conditions control the amount of water entering the soils. As development continues to expand, soil areas that once had a high potential for water retension are paved over or built upon which reduces their holding capacity and increases the volume of runoff. Add other areas of existing development and areas of poor soil which have a high runoff potential and the result is a "snowball effect" that multiplies in cubic feet per second and increases the volume of runoff to be handled down stream. Soil horizons are the differentiation of soil layers that appear on the surface and extend through to bedrock. These horizons will be important to the land use study when it comes to controlling and impounding runoff.

Much of the technical data and calculations for setting development policies will come from the Soil Conservation Services' handbook on hydrology (NEH-4 and TR-55). Therefore, in classifying the soil horizons, we have adopted the hydrologic soil groups as defined by SCS soil scientists. These are "A", "B", "C", and "D", with "A" being the surface soil horizon and then down to the "D" horizon or bedrock. These groups will hold true for any area of the United States with over 4,000 soil types being grouped in one of the four horizons. The horizons as defined by the SCS are as follows:

A. (Low runoff potential). Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.

B. Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

C. Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

D. (High runoff potential). Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Considering the Cary area and again using the Jonesboro Fault line as a reference point, the east side has a generally thin "A" horizon with most of the soils in the "B" horizon category. The Triassic Basin west of the fault line is basically in the "C" and "D" horizons.

One last point to consider when discussing the soils is their location on the surface as to slope. The most suitable soils for development that require the least amount of building guidelines are on the hills and along the ridges. As we move down the side of a typical ridge line, the soils change in character and horizon, and may require better defined and controlled building restrictions.

In the lower sections of the watershed region the soils again change, lending themselves to different development criteria especially areas around the streams and rivers where the soils form portions of the flood plains.

In every case of preparing a Land Use Plan, the soils present the greatest impact. The information touched on in this publication will be used as a means to produce the most comprehensive research for the best utilization of development on the most appropriate soil types.

Vegetation Analysis

The two most visible natural aspects of our land is the vegetation cover and the slope of the land. These two characteristics add another dimension to the process of evaluating and reaching the most consistant and comprehensive land use plan.

Vegetation cover does more than enhance our perception of nature. It is an important asset to the hydraulic system. Depending on the type vegetation cover and the hydrologic condition, vegetation affects runoff volume through its influence on the infiltration rate of the soil. The Planning Department used the same base maps as the soil study to outline the different levels of vegetation cover. All total, thirty-nine (39) maps were involved in this study. The vegetation cover was divided into six (6) categories which the Planning Department felt would contribute the most to the watershed management process.

Following are the vegetation classifications with the corresponding color codes and several of the completed vegetation maps:

(1) Upland Pine: (mint green) This is the area along the tops of ridges and hills where the vegetation is pine stands. There is, in most cases, little understory other than grass or briars. This vegetation stays green year around.

(2) Upland Hardwoods: (light green) Hardwoods are deciduous, which means they lose their leaves each year. These are located in the same general area as the upland pine and mainly consist of oak, hickory, chestnut, elm and ash. The understory consist of less mature species of those mentioned above such as small dogwoods and underbrush.

(3) Mixed Forest: (yellow) The largest percent of vegetation cover falls under this category. These are pine and hardwood. If twenty (20) percent of a forested area was visibly either pine or hardwood, the cover is considered mixed. These areas extend along the tops of ridges and down along the slopes.

(4) Bottomland Pine: (yellow green) This vegetation cover extends along the slopes of the ridgeline down to the flood plain areas.

(5) Bottomland Hardwood: (olive green) This type vegetation cover extends on to the same areas as bottomland pine and again are the deciduous trees.

(6) Riverine: (dark green) These areas are located along the streams. They can extend out several hundred feet from the stream bank itself. The most dominate species are oaks, birch, red maple and hemlock. The ground is very moist so there is a great abundance of undergrowth.

The sections in white are the pasture and open grass lands and the urbanized areas. In the final analysis, the urbanized areas will be considered separately according to the density and the percent of impervious surface cover.

Vegetation cover is a natural means of retention for runoff and controlling sedimentation. In the Cary community, little difference is seen between the general vegetation cover for each watershed except in the percent of urbanization. The more urbanization and less vegetation cover, the greater the exposure to erosion and the problems that storm runoff can create. As we consider the surface cover, our major concern is hours it contributes to the water retention system and the consequences involved when this cover is eliminated for one purpose or another.

The underlining factor for vegetation cover is its "litter" or the debris that is a result of the forest; leaves, needles, twigs, bark, and other vegetative debris on the forest floor. From this litter is formed humus. Humus is the organic layer immediately below the litter and with proper use, protection, and natural status it can be porous and have a high infiltration rate as well as a high storage capacity. The breakdown of debris from hardwoods is faster in forming humus but because of the surface created by the leaves of these deciduous trees,thus water has a tendency to runoff faster and does not allow the water to infiltrate deeply in the soil. On the other hand, the humus layer is deeper which enhances

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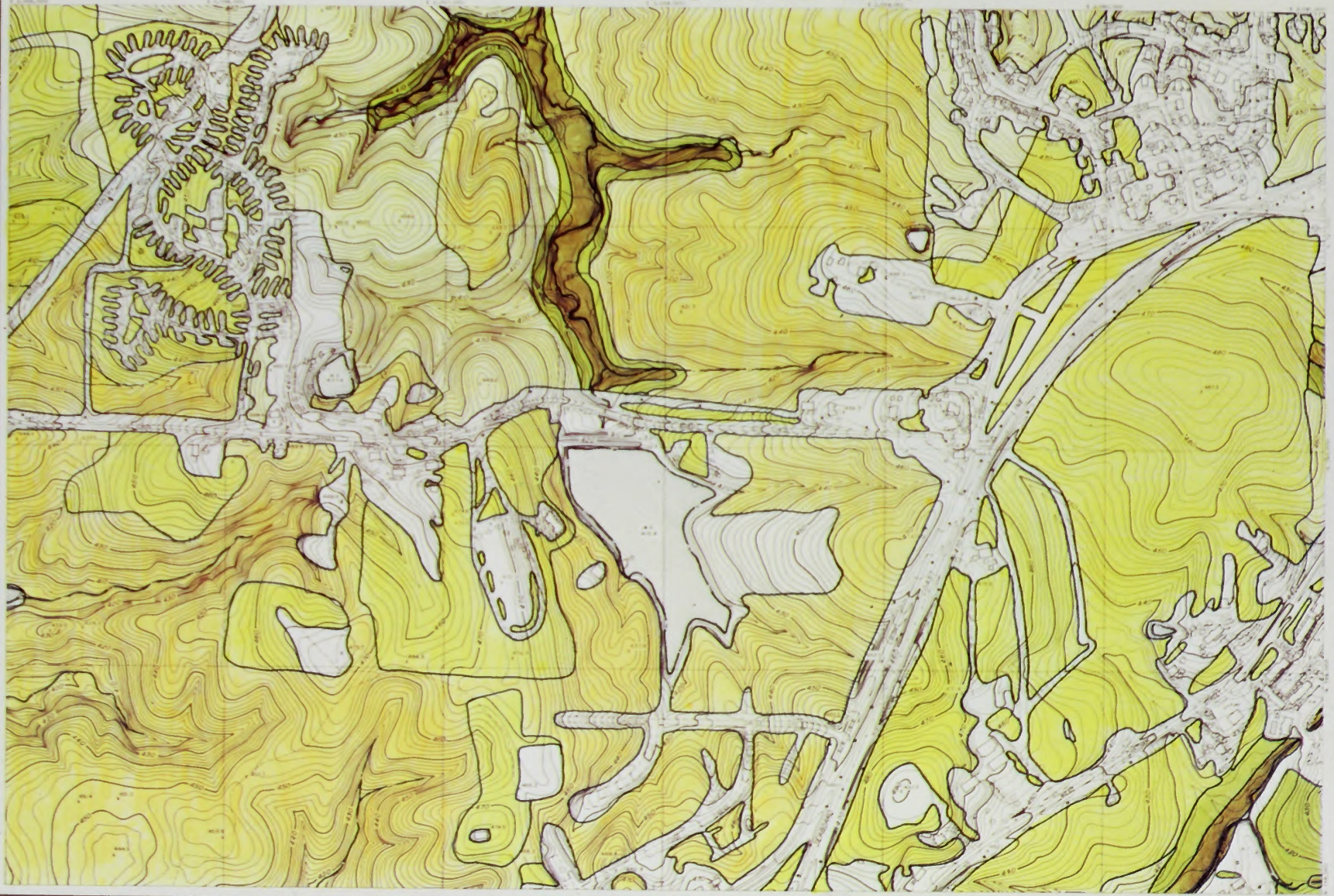


LEGEND

CARY

VEGETATION MAP

LANDMARK ENGINEERING CO INC

27	28	29
22	23	24
17	18	19

TOWN OF

CARY

NORTH CAROLINA

CARY, N. C. AND VICINITY

LEGEND

CARY

VEGETATION MAP

LANDMARK ENGINEERING CO. INC.

23	24	25
18	19	20
13	14	15

TOWN OF

CARY

NORTH CAROLINA

the ability to retain water and the litter layer is thicker which protects the humus from oxidation. This means the humus is preserved longer which adds to the storage capacity for runoff.

In a pine forest, the opposite occurs. Because of the needle structure, water is able to penetrate more deeply into the soil. The process of forming humus is not as rapid nor is the depth of humus as great as in a hardwood forest due to the thin litter layer, which encourages the oxidation process. One can counteract the other in the ability to store water, but a lot also depends on the soil type and slope which the vegetation inhabits. From this discussion, it would be logical to assume the mixed forest of pines and hardwoods would promote the maximum capability to increase water retention.

Development does not have to be negative towards vegetation cover or its importance in the environmental system, but with a logical understanding and the use of this information we can work with and around the sensitive areas, without complete exposure of land surface, to meet the needs of our time. This is where planning and implementing design techniques can be readily used and introduced into our land use plan with visibly satisfying results.

Slope and Elevation Analysis

Slopes are another characteristic of the watershed planning units that affect the development of land. As a general rule, developing on slopes of greater than 15% special consideration to the building and surrounding land are essential. There is no law that restricts building beyond a certain slope percentage, but the laws of nature seem to provide enough hardship when special building requirements are neglected and stripping the vegetation cover on steep slopes occur.

Elevations also are considered as a factor in land use planning. This study provides an excellent relief of Cary's planning area and helps in determining the variation of contour lines between watersheds. Each elevation segment

was considered in twenty (20) feet contour intervals and ranged from 300 feet up to 520 feet above sea level. Again, using the same 39 base maps as before, the elevations for Cary were plotted. One of these maps is included on the following page. A note of interest for Caryites, is the highest elevation within Cary's present planning jurisdiction is Cary Elementary School.

Turning back to slopes, these will have ā much more significant influence on development criteria than elevations. Elevation gives more of an impression of the lay of the land, whereas slopes become another factor, along with soils and vegetation, in controlling the amount of storm water runoff for each watershed. The same 39 base maps were used for the slope study with a legend for percent of slopes as follows:

0 - 3% (yellow)

3 - 8% (tan)

8 -15% (light brown)

15 -25% (gray)

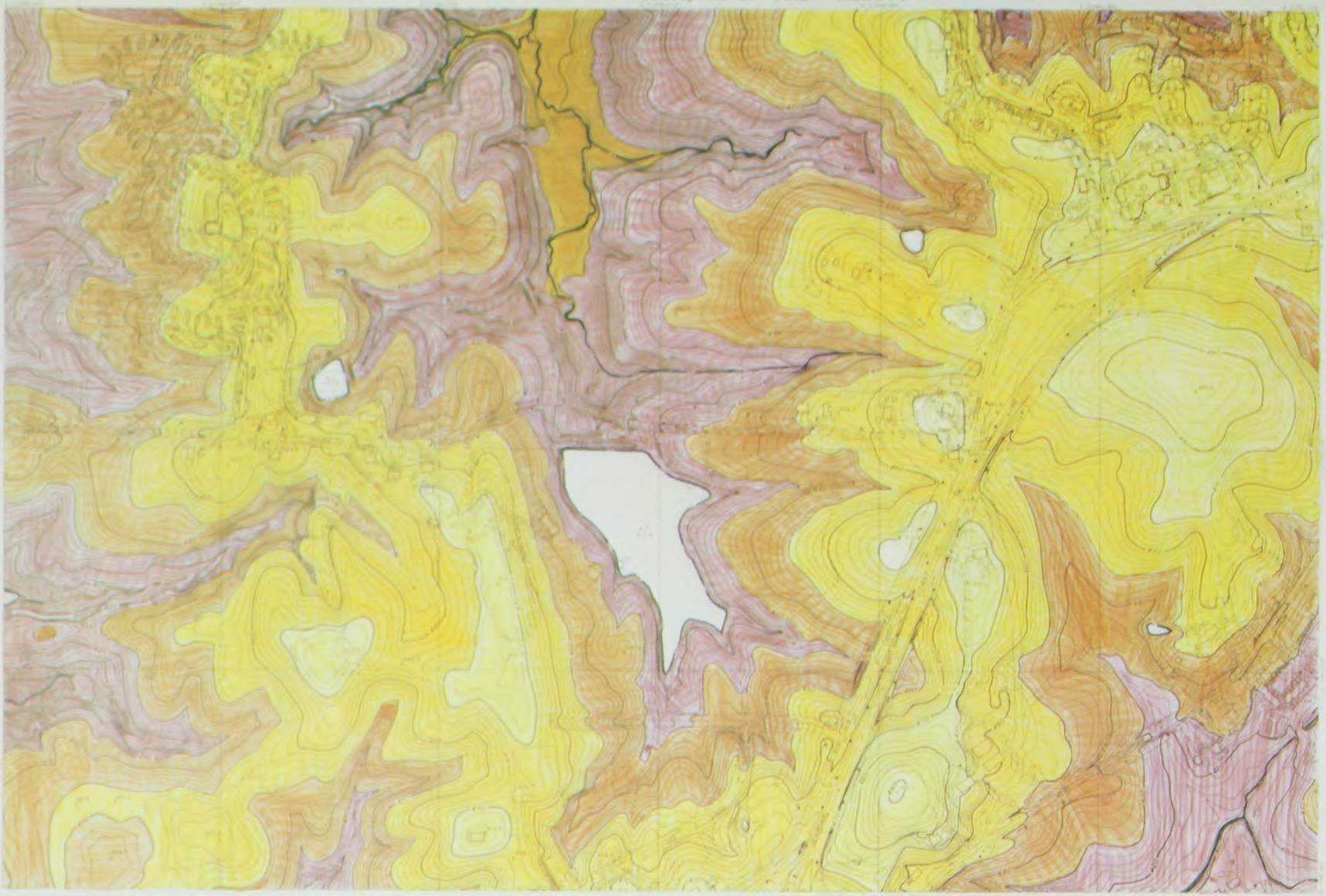
25% + (dark brown)

An example of the slope map is included along with the elevation map.

Slopes dictate, along with the other characteristics of the land, the amount of surface runoff that will reach a stream channel and the time it takes for the watershed to reach its maximum peak discharge.

The steeper the slope, the higher the quantity and velocity of water that will run off the land surface which thus, reduces the chance of any infiltration into the subsurface. In contrast, as the slopes level out, the potential is greater for the storm water to penetrate the soils, thus reaching their saturation point before runoff occurs. Due to these circumstances, the time that it takes for a watershed to reach its peak discharge will vary according to the water retention capabilities of the soil and the percentage of slope.

CARY, N. C. AND VICINITY



CARY

ELEVATION MAP

LANDMARK ENGINEERING CO., INC.

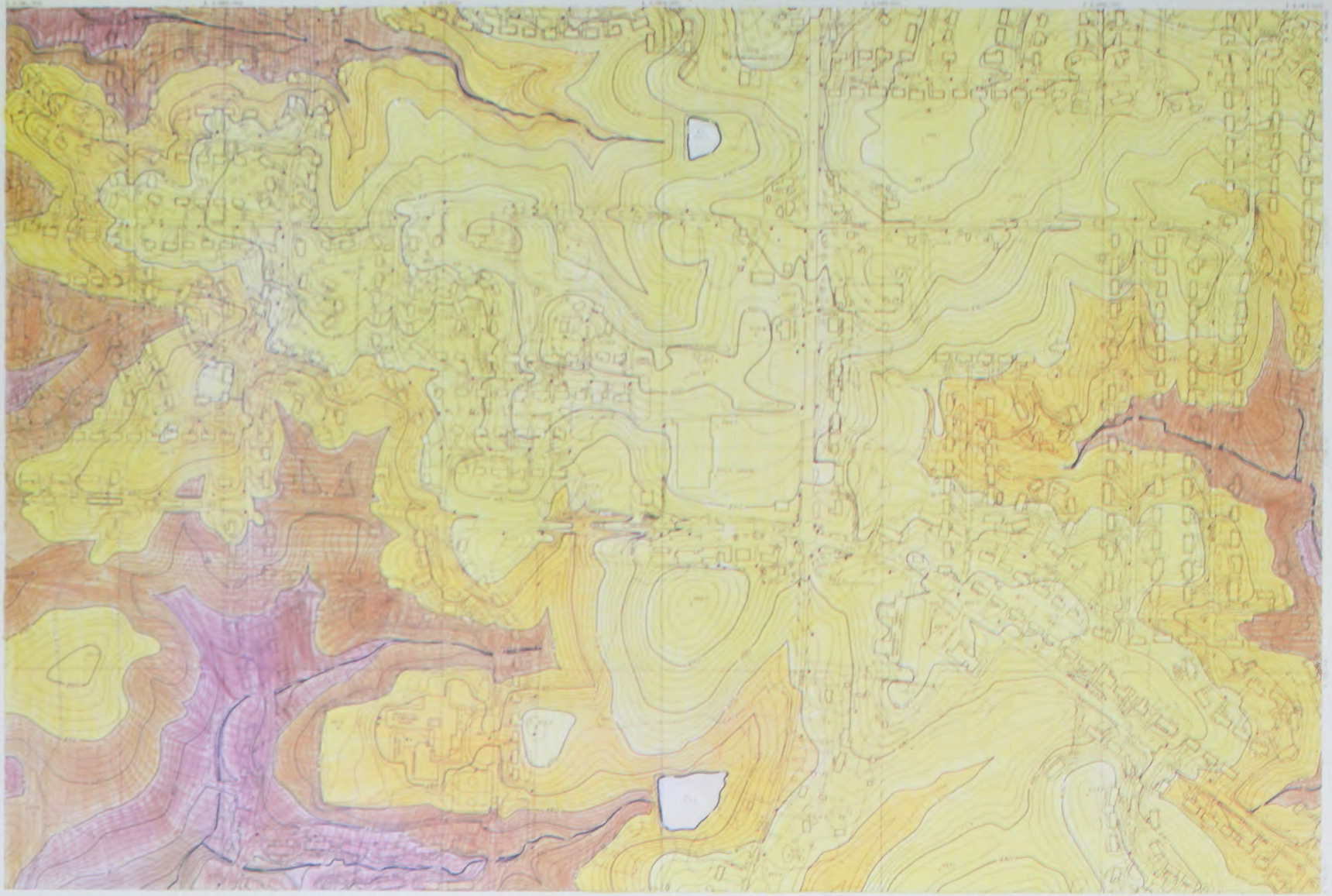
27	28	29
22	23	24
17	18	19

TOWN OF

CARY

NORTH CAROLINA

CARY, N. C. AND VICINITY



LEGEND

CARY

ELEVATION MAP

LANDMARK ENGINEERING CO. INC.

23	24	25
18	19	20
13	14	15

TOWN OF

CARY

NORTH CAROLINA

CARY, N. C. AND VICINITY

LEGEND

CARY

SLOPE MAP

27	28	29
22	23	24
17	18	19

TOWN OF

CARY

NORTH CAROLINA

In the process of evaluating our lands capabilities, slopes need the attention of both the planner and developer. Locating on the more desirable slopes is a common practice, but even here problems may result. Even though these areas have the best water retention capability, through the use of impervious material and building structures, this capability is reduced. Along with the less acceptable slope(steep slopes) increasing the velocity of surface flow, the watershed may exceed its own natural control of the rate of runoff at the stream outlet.

Flood Plains

The final base information is the assessment and delineation of the flood plain areas within Cary's planning jurisdiction, of which Cary has adopted a set of official flood plain maps. According to the subdivision ordinance, all development has to conform to the adopted maps, as determined by calculating for a fifty (50) year frequency storm. The soil maps indicate the flood plain by alluvial soils (blue) which may vary to some degree with what the actual flood plain would include. The Engineering Department has on file the flood plain area within the corporate limits of Cary and has the means available, along with the Planning Department, for determining the flood plain lines for a developer or individual owner upon request. By the absence of structural forms in flood plain areas, this relieves some of the burden on our land resources and time comsuming administrative and legal entanglements for the community.

Summary

What value and true utilization is derived from these base maps will inevitably be the difference between a sound comprehensive land use plan and serious development problems which could possibly threaten the health and well-being of Cary and its citizens.

In the research to assemble all the base maps discussed in this publication, the main concern was the management of water, just as the name "Watershed Planning Unit" implied. The flow of water within the natural system of nature, the action and reaction of water as it moves over and through the land surface, and the impact water has on our everyday lives set the direction for Cary's land use plan. Consequently, as we build, the demand increases to eliminate the hazards created by storm runoff due to urbanization. To this point, the feeling may be that there should not be any development because of the potential problems burdening our land, which in fact is true, but urbanization is irrevocable and a part of civilation, as is nature itself. Therefore, with this thought in mind, the Planning Department began to determine the most expedient and logical approach to find an interim land use system which would expand our urban motivations and at the same time protect our environment. The natural displacement of water provided the specific criteria to meet these needs. It was the most prominent relationship between us and nature, and provided the guidelines for studying the physical land characteristics; soils, vegetation slopes, elevations, flood plain, and water quality. The reactions of these features are in a large respect affected by the presence and movement of water through natural and man-made conditions. By the use of the Watershed Planning Unit and its characteristics, the Planning Department established these as constants for deriving a system of comprehensive planning, sensitive to our environment, aimed at preserving our natural amenities, as well as advocate urban growth.

In the remaining sections of this publication, our attention will be directed to how these base maps along with the hydraulic system are technically applied to the planning process to determine a Comprehensive Land Use Plan that would approach harmony with our environment.

METHODOLOGY

EFFECTS OF URBANIZATION

Management of water runoff from any standpoint is becoming just as important as a municipality providing the needed public services to its community. We have discussed what a watershed is and how its land characteristics relate to the environment. This next section analyzes the effects of urbanization on watershed planning and presents a method for managing runoff volume and peak rates of discharge. This method is a highly technical approach to the urban development of watershed planning units and is based on the studies and information available by the Soil Conservation Service, Engineering Division, in their publications NEH-4 and TR-55. Due to the constant change from rural to urban and adapting to this change, our methods are a preliminary approach to watershed management. As our analysis dictates, we will change or alter our methods to accomplish the desired technical procedures to assist Cary in assessing the affects of land use changes on the watershed planning units.

An urban watershed can be defined as an area in which a percentage of the watershed is, or will be, covered by impervious structures. These include roads, parking lots, sidewalks, and building structures as well as supplementing natural stream systems for drainage, like curb and gutter or storm sewers. Cary has a wealth of undeveloped land which is considered rural because of no sewer or water, even though it is zoned. It will be important to consider the present and future conditions of a watershed as to its percent of urban land (sewered) and rural land (unsewered) so as not to hinder urban development. At the same time, it is necessary to maintain a constant balance between us and nature to control the volume of runoff and the time it takes for this runoff to meet its maximum peak discharge.

If a watershed sustains its natural status which includes agricultural uses, watershed management under these conditions is not as complicated as it is when the effects of urbanization are considered. Investigations into this aspect are necessary to evaluate the magnitude of runoff in order to alter development standards which reflect the changing environment of a watershed. In analyzing these changes, it is important to understand certain factors.

Watersheds alter their sensitivity to rainfall (precipitation) depending on the percent of urban expansion. The most common consequence of this is reduced infiltration and a shorter travel time for the storm water runoff to reach a designated point on a stream which results in a higher rate of runoff. The volume of runoff is determined by the amount of precipitation and by infiltration related to soils, vegetation cover, antecedent rainfall, imprevious material, and surface retention. Travel time, on the other hand, is affected by the slopes, channelization and the surface over which runoff must flow. The peak rates of discharge for runoff are based on the above factors along with the size of the drainage area of a watershed, the percentage of development and the location of development within the watershed. Also, peak discharge is related to rainfall distribution which the Soil Conservation Service has grouped into three types: 1, 1A, and II. Type II distribution, is the one that applies to Cary's region. Rain distribution is the quantity of rain that covers an area within a twenty-four hour period. These factors will be a constant consideration throughout the entire watershed planning unit management system.

It has been discussed at length, the effects of urbanization on soils, vegetation cover, and slopes by studying the base maps. We need to expand this knowledge to include additional data which will influence the watershed planning process. These items mentioned previously need only a brief explanation.

(a) Antecedent moisture conditions (AMC) are indexes of watershed wetness, as described by SCS, and are determined in three ways:

AMC-I is the lowest runoff potential. The watershed is considered to be dry.

AMC-II is the average condition.

AMC-III is the highest runoff potential. A watershed in this nature is practically saturated from rain.

In adapting to these conditions, AMC-II is used as a bases for Cary because of its climatalogy and the amount of precipitation which occurs annually and because AMC-II would not require large adjustments due to extended dry or rainy periods.

(b) Channelization is a common occurrence with urbanization. What this means is natural stream networks which once meander through a watershed, are straightened, relocated, dredged, and substituted for concrete channels. This enhances the time and speed of runoff to reach its peak discharge and ultimately increases runoff volume.

(c) Surface material, known as surface roughness, decreases the velocity of runoff when woodlands and natural cover is substituted for the smooth surfaces of parking lots, roofs, storm sewers and gutters.

With these added parameters, the true impact of urbanization on watersheds can be incorporated into watershed management and insure a positive conclusion by which to base development growth patterns. In order to solidify these standards as a part of the land use plan the method employed by SCS was used which include volume parameters and time parameters. This in itself is not revolutionary for urban planning, but where the watershed system is unique, is when it is applied to Cary. The Planning Department took this system and programmed it to meet the standards and needs of Cary based on the land characteristics, urban development, projected growth and existing land use zoning.

CURVE NUMBERS

Setting aside urban effects for a time, our first requirement is to establish runoff volumes based on the relationship between the watershed's land characteristics and existing land use. The most proficient approach to this is to use curve numbers (CN) to measure volumes of runoff. A curve number is a numerical figure that represents the total volume of runoff for a given area due to soil type and vegetation cover. These numbers have no significance in quantifying a measured volume of runoff; they only represent a high and low scale for runoff.

The curve numbers range from zero (0) to one hundred (100). A low CN means less volume of runoff and a higher CN means a greater volume of runoff. An example would be a forest area with excellent vegetation and humus cover could have a CN as low as twenty-five (25) while an imprevious surface such as a parking lot yields a CN as high as ninety-eight (98). Storm rainfall and stream flow data for annual floods are the best means to determine CN figures. However, this involves the use of gages at different locations within a watershed which is very time consuming and expensive. Therefore, the Planning Department used a more conventional method which was also very time consuming, but with little expense. This involved use of the base maps to a large extent. If you will recall in looking at the soils, there were four horizons (A,B,C, & D). SCS has classified each soil in one of these horizons. Our concern was to determine what urban soil suitability group belonged to which soil horizon. Upon this determination, each soil map was overlaid with its corresponding vegetation map. Using the SCS table (see Chart 1), for hydrologic soil cover complexes, we then determine the CN relative to Cary's existing soil and vegetation conditions.

All the curve numbers of Chart-1 are based on an AMC-II and Ia=0.2.S. The AMC-II we know, the Ia is the initial abstraction in inches and consist of interception (rain caught by foliage, twigs, branches, leaves, etc.), infiltration and surface

Chart 1 -- Runoff curve numbers for hydrologic soil-cover complexes

(Antecedent moisture condition II, and I_a = 0.2 S)

Land use	Cover: Treatment or practice	Hydrologic condition	Hydrologic soil group: A	B	C	D
Fallow	Straight row	---	77	86	91	94
Row crops	"	Poor	72	81	88	91
	"	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	"	Good	65	75	82	86
	" and terraced	Poor	66	74	80	82
	" " "	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	" and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes 1/ or rotation meadow	Straight row	Poor	66	77	85	89
	" "	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	"	Good	55	69	78	83
	" and terraced	Poor	63	73	80	83
	" " "	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	"	Fair	25	59	75	83
	"	Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		---	59	74	82	86
Roads (dirt) 2/		---	72	82	87	89
(hard surface) 2/		---	74	84	90	92

1/ Close-drilled or broadcast
2/ Including right-of-way

Soil Conservation Service, Hydrology Section 4, U. S. Department of Agriculture, Washington, D. C., 1972, page 9.2

storage, all of which occur before runoff, and must be satisfied before runoff begins. The (S) in this formula is the potential abstraction and is related to the soil and vegetation cover. To determine S, the formula is:

$$S = \frac{1000}{CN} - 10$$

Since the CN is also related to soil and vegetation cover, we can determine the CN as follows:

$$CN = \frac{1000}{S+10}$$

Again, SCS has made matters easy by providing a table (see Chart-2) with all moisture conditions and the (S) for AMC-11.

To better understand what Chart-2 conveys, 100 means total runoff and no rentention of water due to infiltration, interception and surface storage as indicated by the zero in the (S) column. At the other end of the spectrum is 5 for AMC-11, which means a very high water retention capability before runoff begins, because of the above abstractions as shown by the (S) value of 190.0. As the most appropriate CN's to suit Cary's needs are described, this chart will provide a total picture of the meaning of each curve number.

Direct Runoff

We have examined runoff in terms of volume which will be the initial factor in watershed management procedures, but there has to be a more visible relationship between the curve numbers and direct runoff. This is possible with an equation to estimate the actual direct runoff (Q) in inches by using the following formula:

$$Q = \frac{(P-0.2S)^2}{P + 0.8S}$$

By knowing (P) which is precipitation in inches, and the curve number from which (S) can be determined, the direct runoff, in inches, for a given CN can be equated. Chart-3 indicates runoff depths in inches for certain CN's and the corresponding amounts of rainfall. For Cary, a rainfall of 5.6 inches was used to

Chart 2 -- Curve numbers (CN) and constants for the case I_a = 0.2 S

1	2	3	4	5	1	2	3	4	5
CN for condition II	CN for conditions I	CN for conditions III	S values*	Curve* starts where P =	CN for condition II	CN for conditions I	CN for conditions III	S values*	Curve* starts where P =
			(inches)	(inches)				(inches)	(inches)
100	100	100	0	0	60	40	78	6.67	1.33
99	97	100	.101	.02	59	39	77	6.95	1.39
98	94	99	.204	.04	58	38	76	7.24	1.45
97	91	99	.309	.06	57	37	75	7.54	1.51
96	89	99	.417	.08	56	36	75	7.86	1.57
95	87	98	.526	.11	55	35	74	8.18	1.64
94	85	98	.638	.13	54	34	73	8.52	1.70
93	83	98	.753	.15	53	33	72	8.87	1.77
92	81	97	.870	.17	52	32	71	9.23	1.85
91	80	97	.989	.20	51	31	70	9.61	1.92
90	78	96	1.11	.22	50	31	70	10.0	2.00
89	76	96	1.24	.25	49	30	69	10.4	2.08
88	75	95	1.36	.27	48	29	68	10.8	2.16
87	73	95	1.49	.30	47	28	67	11.3	2.26
86	72	94	1.63	.33	46	27	66	11.7	2.34
85	70	94	1.76	.35	45	26	65	12.2	2.44
84	68	93	1.90	.38	44	25	64	12.7	2.54
83	67	93	2.05	.41	43	25	63	13.2	2.64
82	66	92	2.20	.44	42	24	62	13.8	2.76
81	64	92	2.34	.47	41	23	61	14.4	2.88
80	63	91	2.50	.50	40	22	60	15.0	3.00
79	62	91	2.66	.53	39	21	59	15.6	3.12
78	60	90	2.82	.56	38	21	58	16.3	3.26
77	59	89	2.99	.60	37	20	57	17.0	3.40
76	58	89	3.16	.63	36	19	56	17.8	3.56
75	57	88	3.33	.67	35	18	55	18.6	3.72
74	55	88	3.51	.70	34	18	54	19.4	3.88
73	54	87	3.70	.74	33	17	53	20.3	4.06
72	53	86	3.89	.78	32	16	52	21.2	4.24
71	52	86	4.08	.82	31	16	51	22.2	4.44
70	51	85	4.28	.86	30	15	50	23.3	4.66
69	50	84	4.49	.90					
68	48	84	4.70	.94	25	12	43	30.0	6.00
67	47	83	4.92	.98	20	9	37	40.0	8.00
66	46	82	5.15	1.03	15	6	30	56.7	11.34
65	45	82	5.38	1.08	10	4	22	90.0	18.00
64	44	81	5.62	1.12	5	2	13	190.0	38.00
63	43	80	5.87	1.17	0	0	0	infinity	infinity
62	42	79	6.13	1.23					
61	41	78	6.39	1.28					

*For CN in column 1.

Soil Conservation Service, Hydrology Section 4, U. S. Department of Agriculture, Washington, D. C., 1972, page 10.7.

Chart 3 -- Runoff depth in inches for selected CN's and rainfall amounts

Rainfall (inches)	Curve Number (CN)[1/]								
	60	65	70	75	80	85	90	95	98
1.0	0	0	0	0.03	0.08	0.17	0.32	.56	.79
1.2	0	0	0.03	0.07	0.15	0.28	0.46	.74	.99
1.4	0	0.02	0.06	0.13	0.24	0.39	0.61	.92	1.18
1.6	0.01	0.05	0.11	0.20	0.34	0.52	0.76	1.11	1.38
1.8	0.03	0.09	0.17	0.29	0.44	0.65	0.93	1.29	1.58
2.0	0.06	0.14	0.24	0.38	0.56	0.80	1.09	1.48	1.77
2.5	0.17	0.30	0.46	0.65	0.89	1.18	1.53	1.96	2.27
3.0	0.33	0.51	0.72	0.96	1.25	1.59	1.98	2.45	2.78
4.0	0.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
5.0	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
5.6	1.67	2.06	2.49	2.94	3.42	3.93	4.46	5.01	5.37
6.0	1.92	2.35	2.80	3.28	3.78	4.31	4.85	5.41	5.76
7.0	2.60	3.10	3.62	4.15	4.69	5.26	5.82	6.41	6.76
8.0	3.33	3.90	4.47	5.04	5.62	6.22	6.81	7.40	7.76
9.0	4.10	4.72	5.34	5.95	6.57	7.19	7.79	8.40	8.76
10.0	4.90	5.57	6.23	6.88	7.52	8.16	8.78	9.40	9.76
11.0	5.72	6.44	7.13	7.82	8.48	9.14	9.77	10.39	10.76
12.0	6.56	7.32	8.05	8.76	9.45	10.12	10.76	11.39	11.76

1/ To obtain runoff depths for CN's and other rainfall amounts not shown in this table, use an arithmetic interpolation.

Soil Conservation Service, Urban Hydrology for Small Watersheds, Technical Release No. 55, U. S. Department of Agriculture, Washington, D. C., 1975, page 2-3.

represent (P) for the watershed planning units based on Cary's Sedimentation and Erosion Control Ordinance, which requires retention standards for a 10-year frequence storm and data from the U. S. Weather Bureau Service.

Watershed planning, using the natural land characteristics, handles runoff to a degree, but the existing land use has a tremendous impact on a watershed; therefore, just the physical characteristics are not enough. The effects of urbanization needs to be incorporated into the watershed system, which uses the same calculations and charts, but also includes the percentage of impervious material, density per acre of land, and modification to stream channels.

Urban Runoff

The increase in volume of runoff because of urbanization depends more on the percentage of impervious area than any other watershed constant attributed to man. By considering land use patterns found under urban conditions and accounting for the percentage of impervious area, a weighted CN can be determined representing runoff potential. Impervious surfaces such as roofs, streets, sidewalks, driveways and parking lots have some initial abstraction before runoff occurs, but nearly 100 percent of the rainfall may run off. Even with such urban conditions, there are also other surfaces to consider. Lawns, parks, play fields, golf courses and greenways are the most obvious and both the initial abstraction and infiltration are more apparent under these conditions.

Urban Curve Numbers

When determining urban curve numbers, there are several factors that have to be taken into account. These are as follows:

(a) The compaction of the soil compared to urban and natural conditions.

(b) Whether the pervious surface has a sufficient layer of vegetation.

(c) The amount of grading involved with the urban project.

(d) The type of vegetation such as grass for lawns and landscaping.

(e) The zoning density per acre of land.

(f) The use of land in relation to commerce and industry.

(g) The percent of impervious material, and

(h) The general building practices or codes for a municipality.

Chart 4 gives the CN's by hydrologic soil groups for agricultural, woodland, surburban and high urban land uses. This chart does not deal specifically with Cary although the only significant difference in this chart and the ones to be devised for each watershed affecting Cary is in the woodland and residential use. Woodlands were divided into six (6) classifications (see vegetation cover), while the average percent of impervious material would not be as great as in Chart-4, because these figures reflect the northeast section of the United States. This will vary the CN's to a small degree. Considering both urban and rural conditions we can now determine the weighted CN for a particular watershed. An example of how to calculate the weighted CN for a typical watershed follows:

A watershed of 2000 acres is 30 percent agricultural (includes undistrubed areas) and 70 percent urban land. The agricultural land is 35 percent cultivated land with conservation treatment, 30 percent meadow (good condition), 10 percent meadow (poor condition) and 25 percent forested land with good cover. The urban area is 60 percent 1/2 acre lots, 20 percent 1/3 acre lots, 5 percent 1/8 acre lots, 10 percent is streets and roads with curb and gutter and storm sewers, 2 percent commercial and business and 3 percent open space (golf course). The watershed is in a B hydrologic soil group. Compute the weighted CN runoff factor and the direct runoff in inches.

Land Use	Acres	CN	Product
Agriculture:	(600)		
Cultivated land (conservation treatment)	210	71	14,910
Meadow (good cover)	180	58	10,440
Meadow (poor cover)	60	79	4,740
Forest (good cover)	150	55	8,250

Chart 4 -- Runoff curve numbers for selected agricultural, suburban, and urban land use. (Antecedent moisture condition II, and $I_a = 0.2S$)

LAND USE DESCRIPTION	HYDROLOGIC SOIL GROUP			
	A	B	C	D
Cultivated land 1/: without conservation treatment	72	81	88	91
: with conservation treatment	62	71	78	81
Pasture or range land: poor condition	68	79	86	89
good condition	39	61	74	80
Meadow: good condition	30	58	71	78
Wood or Forest land: thin stand, poor cover, no mulch	45	66	77	83
good cover 2/	25	55	70	77
Open Spaces, lawns, parks, golf courses, cemeteries, etc.				
good condition: grass cover on 75% or more of the area	39	61	74	80
fair condition: grass cover on 50% to 75% of the area	49	69	79	84
Commercial and business areas (85% impervious)	89	92	94	95
Industrial districts (72% impervious)	81	88	91	93
Residential: 3/				
Average lot size — Average % Impervious 4/				
1/8 acre or less — 65	77	85	90	92
1/4 acre — 38	61	75	83	87
1/3 acre — 30	57	72	81	86
1/2 acre — 25	54	70	80	85
1 acre — 20	51	68	79	84
Paved parking lots, roofs, driveways, etc. 5/	98	98	98	98
Streets and roads:				
paved with curbs and storm sewers 5/	98	98	98	98
gravel	76	85	89	91
dirt	72	82	87	89

1/ For a more detailed description of agricultural land use curve numbers refer to National Engineering Handbook, Section 4, Hydrology, Chapter 9, Aug. 1972.
2/ Good cover is protected from grazing and litter and brush cover soil.
3/ Curve numbers are computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur.
4/ The remaining pervious areas (lawn) are considered to be in good pasture condition for these curve numbers.
5/ In some warmer climates of the country a curve number of 95 may be used.

Soil Conservation Service, Urban Hydrology for Small Watersheds, Technical Release No. 55, U. S. Department of Agriculture, Washington, D. C., 1975, page 2-5.

Urban:	(1400)		
1/2 acre lots	840	70	58,800
1/3 acre lots	280	72	20,160
1/8 acre lots	70	85	5,950
Streets for curb & gutter and storm sewer	140	98	13,720
Commercial & Business	28	92	2,576
Open space	42	61	2,562
	2000		142,108

$$\text{Weighted CN} = \frac{142,108}{2000} = 71.05 \text{ or } 71$$

From Chart-3 with a 5.6 inch rainfall and interpolating the CN for runoff depth in inches, Q = 2.58.

This is only one variation of the many situations to be encountered in watershed planning. This same process will be used in each watershed in Cary's jurisdiction to determine the weighted CN (volume of runoff) under the present land use conditions. Whether this will be a set CN for the maximum runoff allowed to pass from one watershed into another watershed depends on the amount of development each watershed is capable of supporting.

Using the same process and curve numbers, the future CN can be determined by anticipating the percentages of growth through population and economic studies related to the watershed. The Planning Department has completed both of these studies and will use the results to determine the future curve numbers. The future CN will be compared to the present weighted CN and used as the standards for controlling urban development and maintaining a constant level of runoff for each watershed.

Time of Concentration, Travel Time and Lag

Our concern thus far has been with the overall volume of runoff which is only half our concern. It is most important to know how long and at what time this runoff will reach its peak rate of discharge. Without this, the CN would have little impact. The time parameters are the most important as well as the most complicated to assess for watershed management.

Urbanization increases the velocity of runoff from the time it hits the watershed in the form of rain, to the time it reaches the watershed outlet. Time of concentration, travel time, and lag all affect the velocity. Time of concentration (T_c) is the time it takes runoff to travel from the most upper reaches of a watershed to its outlet or a point of reference. It is computed from travel time (T_t) which is influenced by overland flow, storm sewer or flood gutter flow, and channel flow. Lag (L) is a weighted time of concentration and is related to the physical characteristics of a watershed.

Travel time, as we said, is determined by three factors:

(a) Overland flow which is calculated using Chart 5 (average velocities for overload flow), and the formula:

$$T_{t\ \text{in sec.}} = \frac{\text{length of watershed}}{\text{velocity in feet per second}}$$

(b) Storm sewer or road gutter flow can also use Chart 5, and the same formula if the flow length is measured by shallow road gutters. Otherwise, a more complicated calculation is needed. This is Manning's Equation to Compute Average Velocities by which channel flow is determined.

(c) Channel flow requires the use of Manning's Equations which are:

$$v = \frac{1.49}{n} \frac{D^{2/3}}{4} s^{1/2}$$

for pipefull velocity, and,

$$v = \frac{1.49}{n} r^{2/3} s^{1/2}$$

for bankfull velocity.

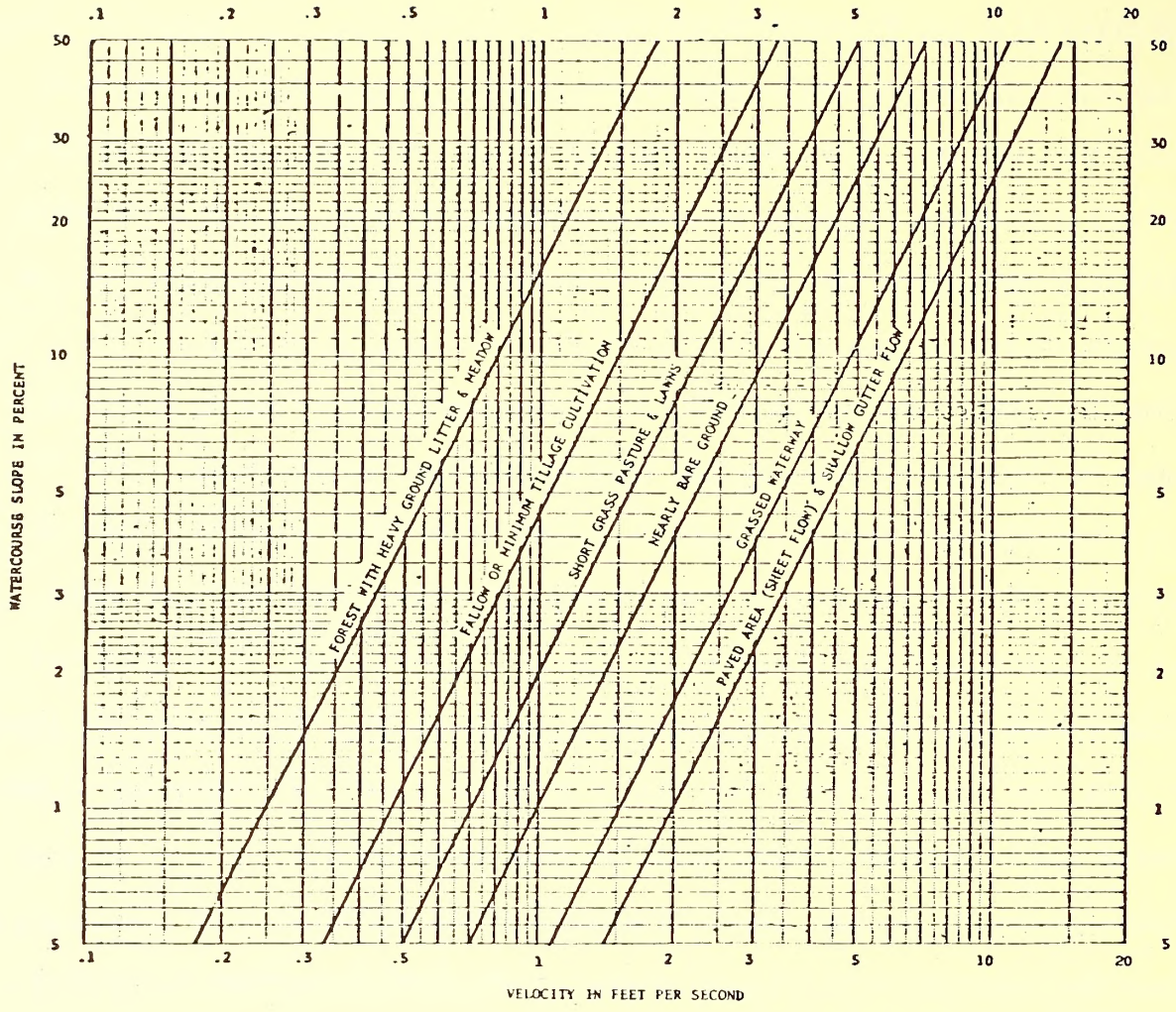


Chart 5 -- Average velocities for estimating travel time for overland flow.

Soil Conservation Service, Urban Hydrology for Small Watersheds, Technical Release No. 55, U. S. Department of Agriculture, Washington, D. C., 1975, page 3-2.

Taking these computations the stream flow conditions can be applied to a given watershed in sections known as reaches from its uppermost area with travel time determined for each reach. The travel time for each reach is then added together and the time of concentration (T_c) is determined as follows:

$$T_{c \text{ in hr.}} = \frac{T_{t \text{ in seconds}}}{(3600 \text{ sec./hr.})}$$

Lag time being the weighted T_c takes into account the length (ℓ) of the watershed, slope (Y) and flow retardance $(S+1)^{0.7}$. The formula for lag is:

$$L = \frac{\ell^{0.8}(S+1)^{0.7}}{1900\ Y^{0.5}}$$

where

L = lag in hours

ℓ = length of watershed in feet

$S = \frac{1000}{CN} = 10$

Y = average percent of slope for a watershed.

Because this formula for lag is oriented to agricultural situations, SCS has found this equation to overestimate lag when considering changes in the main stream and increased amounts of impervious areas. Charts 6, 7, and 8, compute lag taking into consideration these urban conditions. Chart 6 estimates lag for a homogenous watershed under natural conditions up to 2,000 acres. Chart 7 adjusts lag to the main stream channel being improved, and Chart 8 adjusts lag for increased percentage of impervious areas.

Using an example from SCS, the time parameters for runoff can be described as follows:

A watershed of 1,000 acres has a present CN of 75, average slope of 4 percent, and stream length of 13,200. Urban development is expected to modify 70 percent of the stream length and incease the impervious area by 40 percent, and increàse the runoff CN to 80. Compute the present and future time of concentration (T_c).

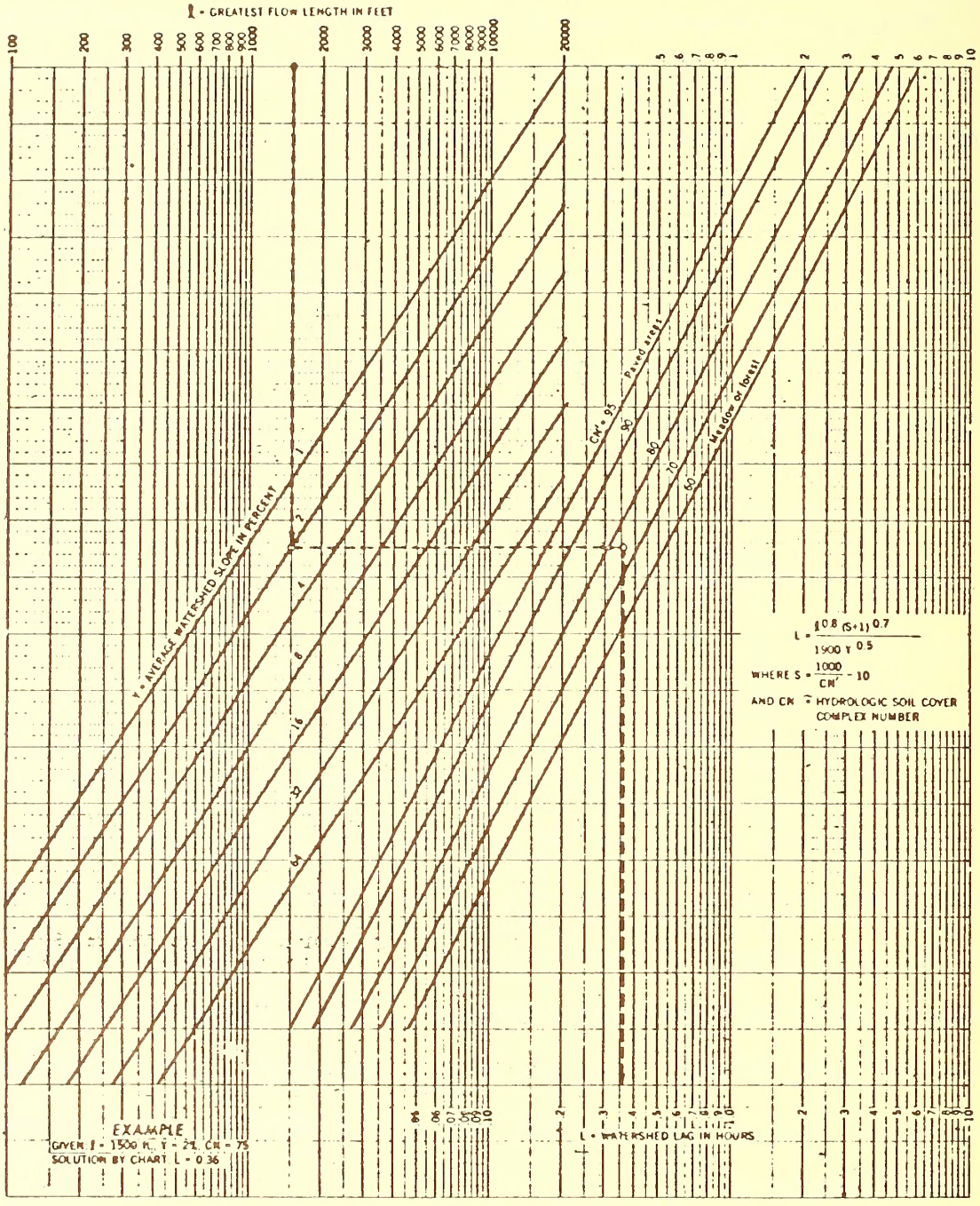

l - GREATEST FLOW LENGTH IN FEET
Y - AVERAGE WATERSHED SLOPE IN PERCENT
CN = 95
90
80
70
60
Paved areas
Meadow or forest
$L = \frac{l^{0.8}(S+1)^{0.7}}{1900\ Y^{0.5}}$
WHERE $S = \frac{1000}{CN} - 10$
AND CN = HYDROLOGIC SOIL COVER COMPLEX NUMBER
EXAMPLE
GIVEN l = 1500 ft, Y = 2%, CN = 75
SOLUTION BY CHART L = 0.36
L - WATERSHED LAG IN HOURS

Chart 6 -- Curve number method for estimating lag (L) for homogeneous watersheds under natural conditions up to 2,000 acres.

Soil Conservation Service, Urban Hydrology for Small Watersheds, Technical Release No. 55, U. S. Department of Agriculture, Washington, D. C., 1975, page 3-7.

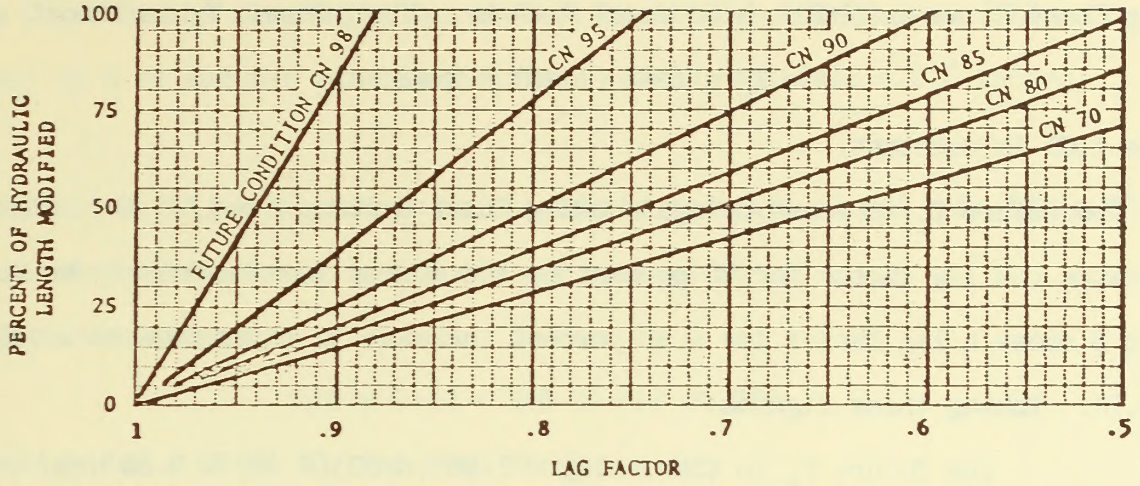


Chart 7 -- Factors for adjusting lag when the main channel has been hydraulically improved.

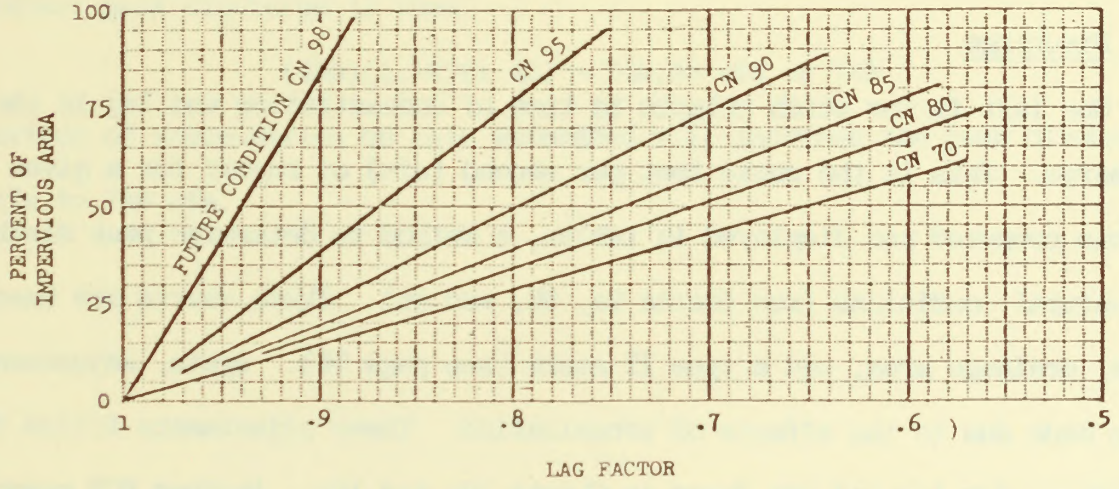


Chart 8 -- Factors for adjusting lag when impervious areas occur in the watershed.

Soil Conservation Service, Urban Hydrology for Small Watersheds, Technical Release No. 55, U. S. Department of Agriculture, Washington, D. C., 1975, pages 3-8 and 3-9.

Using Chart 6, we determine L to equal 1.45 hr. The present T_c is then:

$$T_c = 1.67\ (1.45) = 2.42 \text{ hr.}$$

where 1.67 is constant.

The future T_c is found by again using Chart 6 where L = 1.25 hr. Chart 7 indicates the lag factor for 70 percent of the stream improvements to be 0.59. Chart 8 shows a lag factor for a 40 percent increase in impervious material equal to 0.76. Taking these figures:

the future T_c is then: lag = 1.25 (0.59)(0.76) = 0.56 hrs.

$$T_c = 1.67\ (.56) = .94 \text{ hrs.}$$

The above figures indicate the difference in time it takes runoff to reach a control point due to urbanization. The result of this time change increases runoff volume at a possible rate beyond the normal capability that a watershed can easily maintain.

Peak Discharge

One last factor which relates to time of concentration and lag is the peak discharge. This is the cubic feet per second (cfs) of runoff for a given CN. SCS has computed and displayed in tables, a method to determine peak discharge for natural conditions (see charts 9a, 9b, and 9c). These charts are based on slope, drainage area, and a type II storm (see page 54). Again, adjustments had to be made due to the effects of urbanization. These adjustments follow the same procedures for lag and are found in Charts 10a and 10b. Another SCS example of determining the present peak discharge (cfs) and future discharge from development might appear as follows for Cary:

A 300 acre watershed is to be developed. The CN is projected to be 80. About 60 percent of the watershed stream length will be modified by installing street, gutters, and storm drains. About 30 percent will go to increased impervious area. The average slope is 4 percent. Compute the present and future peak discharge for a ten year storm with 5.6 inches of rainfall. The present CN is 70.

From Chart 3, the runoff (Q) for present conditions (CN=70, rainfall = 5.6 inches) is 2.49 and for future conditions (CN=80, rainfall = 5.6 inches) is 3.42.

From Chart 9a (4 percent slope is considered moderate slope), the CN is 70 so the present peak discharge is 115 cfs per inch of runoff.

The peak discharge is:

$$115 \times 2.49 = 286.35 \text{ cfs or } 286$$

Repeating for a CN of 80, the peak discharge is:

$$133 \times 3.42 = 454.86 \text{ cfs or } 455$$

From Chart 10a, 30 percent impervious area for a future runoff of CN 80 reads a peak factor = 1.16.

From Chart 10b, 60 percent of the stream length is modified by urbanization for CN 80 which reads a peak factor of 1.42.

The future peak discharge is then:

$$(455)(1.16)(1.42) = 749.48 \text{ cfs or } 749$$

The effect of urbanization on this watershed will increase the peak discharge from 286 cfs to 749 cfs.

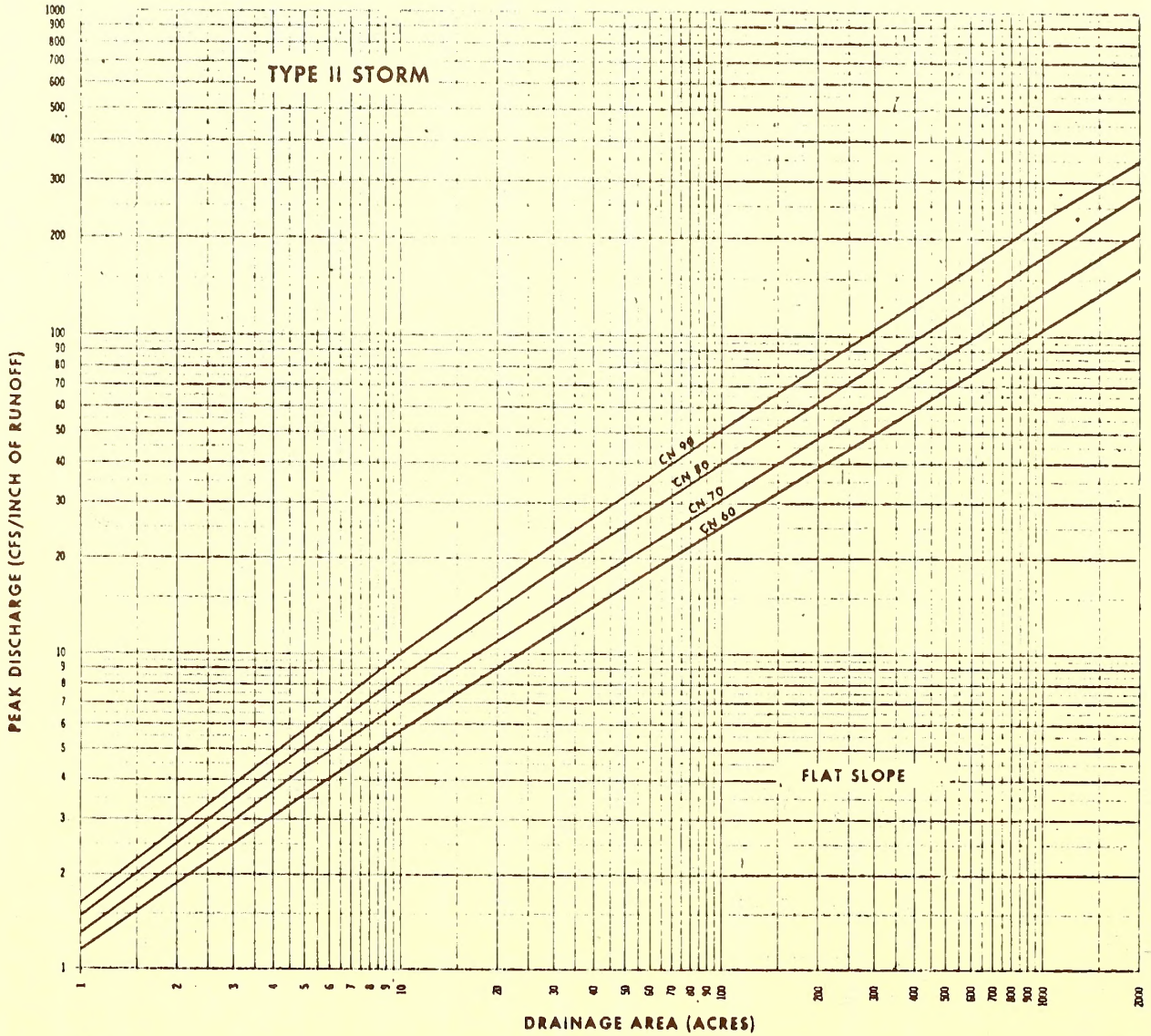


Chart 9a -- Peak rates of discharge for small watersheds (24-hour, type-II storm distribution). Sheet 1 of 3

Soil Conservation Service, Urban Hydrology for Small Watersheds, Technical Release No. 55, U. S. Department of Agriculture, Washington, D. C., 1975, Appendix D.

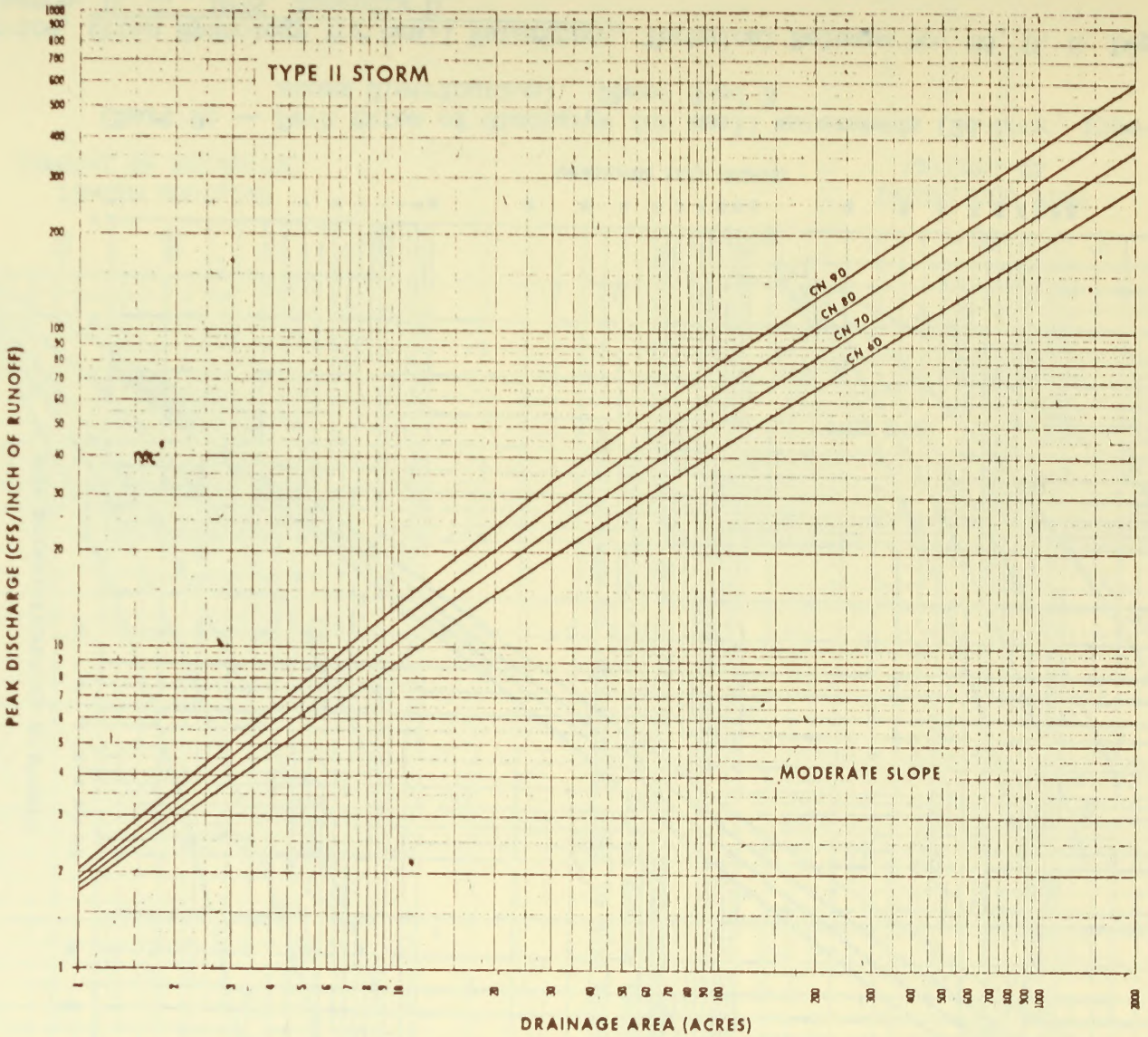


Chart 9-b -- Peak rates of discharge for small watersheds (24-hour, type-II storm distribution). Sheet 2 of 3

Soil Conservation Service, Urban Hydrology for Small Watersheds, Technical Release No. 55, U. S. Department of Agriculture, Washington, D. C., 1975, Appendix D.

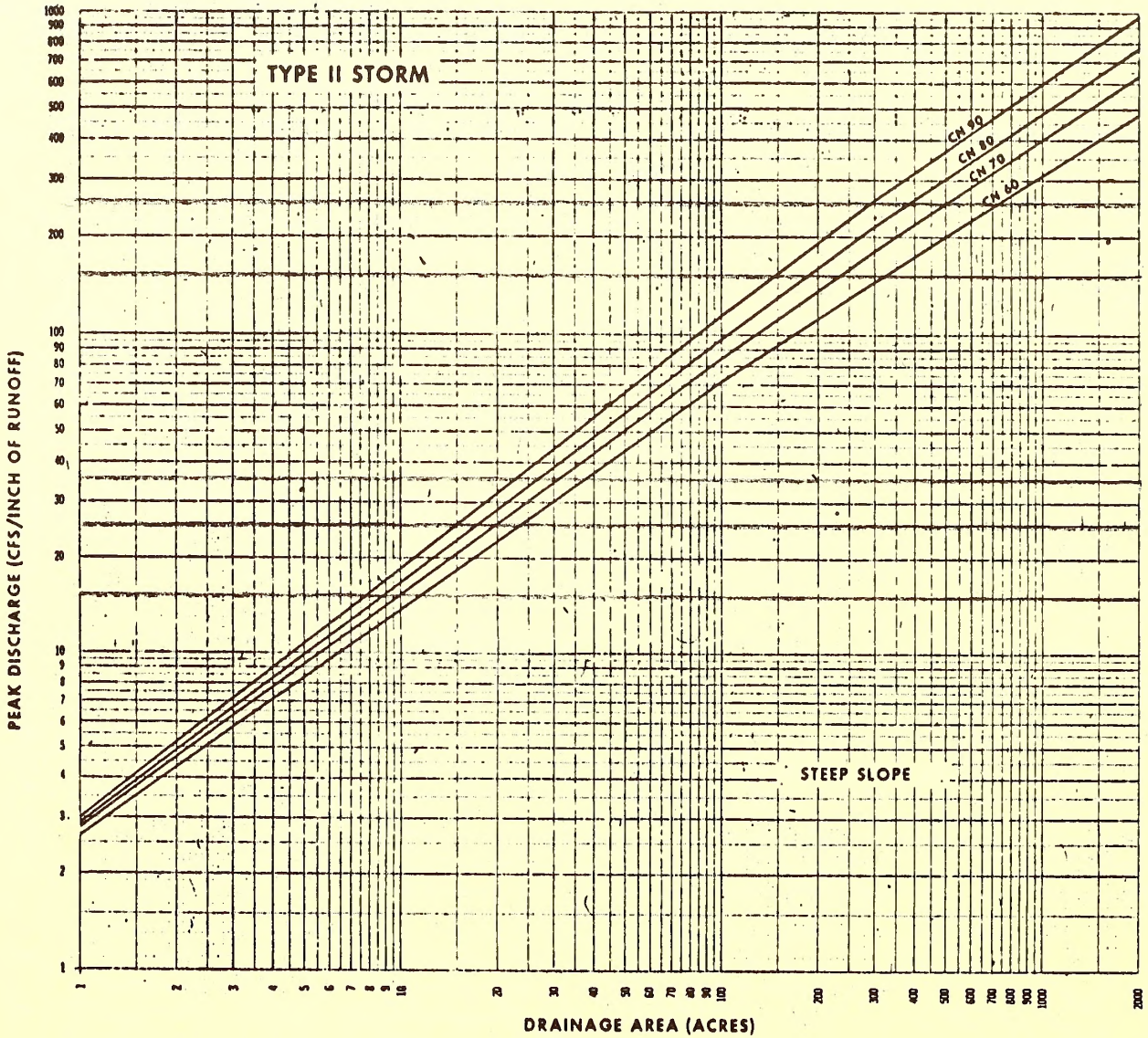


Chart 9c — Peak rates of discharge for small watersheds (24-hour, type-II storm distribution). Sheet 3 of 3

Soil Conservation Service, Urban Hydrology for Small Watersheds, Technical Release No. 55, U. S. Department of Agriculture, Washington, D. C., 1975, Appendix D.

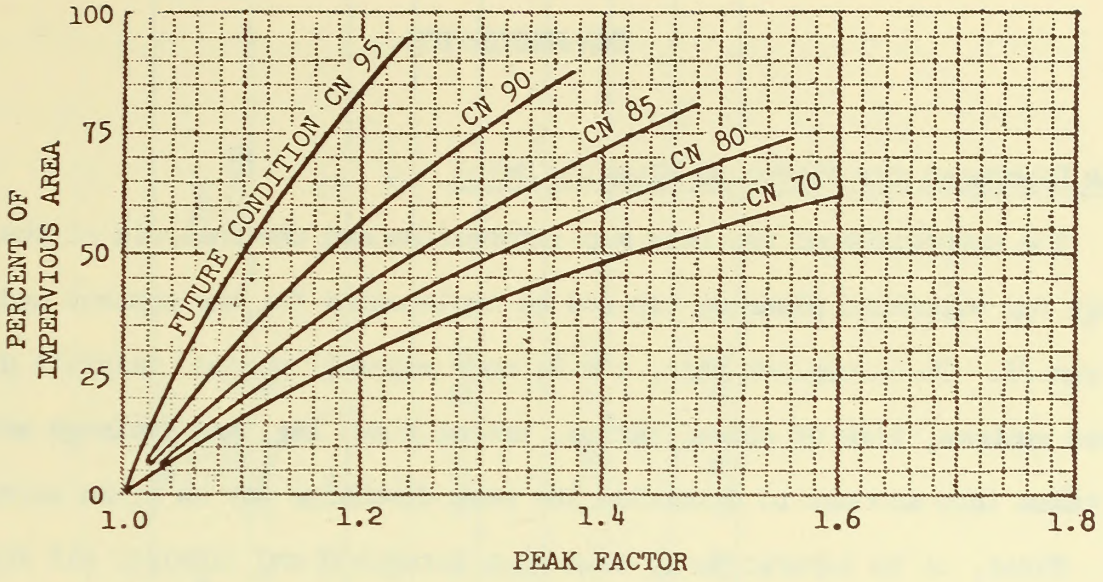


Chart 10a -- Factors for adjusting peak discharges for a given future-condition runoff curve number based on the percentage of impervious area in the watershed.

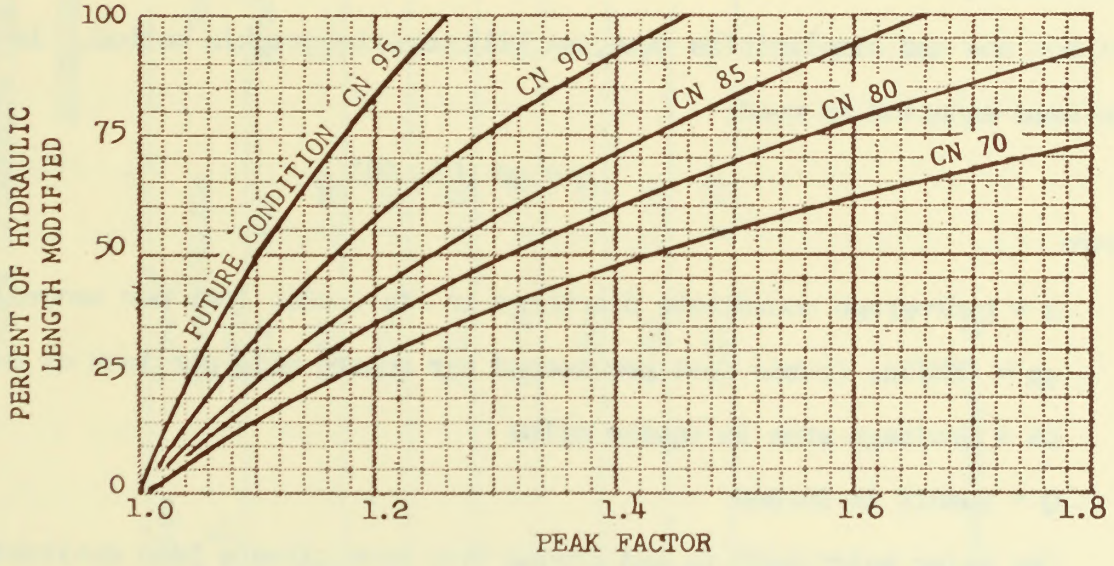


Chart 10b -- Factors for adjusting peak discharges for a given future-condition runoff curve number based on the percentage of hydraulic length modified.

Soil Conservation Service, Urban Hydrology for Small Watersheds, Technical Release No. 55, U. S. Department of Agriculture, Washington, D. C., 1975, page 4-2.

IMPLEMENTATION

Peak Discharge for Watershed Planning Units

The completion of the base map information and the analysis of the methodology for watershed planning can now be implemented for the control and management of runoff. To accomplish this, the 24 hour rainfall period, rainfall distribution, curve numbers, time of concentration, travel time, lag, and drainage area all must be taken into account to determine the peak discharge for an urban watershed.

First, it is imperative to take each watershed and tabulate all the above information for reference such as shown in Table-1 as a hypothetical example.

There are two SCS methods of determining peak discharge for urban watersheds. One is the tabular method, the other the graphical method. The tabular method is lengthy and hard to use, much less explain; however, the end result may be to use this method for Cary. The Planning Department will determine this in the future, but for now and simplicities sake, we will use the graphic method. In either case, the same equation is used:

$$q = qp\ (DA)\ (Q)$$

where

q = hydrograph coordinate discharge in cfs (cubic feet per second)

qp = CSM/in. (cubic feet per second per square mile per inch of runoff)

DA = drainage area in square miles

Q = runoff in inches

The major watersheds in and around Cary have already been outlined (see watershed map). Each will be assessed and evaluated by SCS methods to determine what the maximum volume of runoff and peak discharge is needed to protect against flooding and sedimentation. Then each sub-watershed within the major watershed will be labeled with its own control measures, again using the SCS method. Just

TABLE 1-COMPOSITE TABLE FOR A WATERSHED

WATERSHED # 10

Sub-Area (Watershed)	Drainage Area (mi. ^{2})	Time of Concentration (hrs.)		Runoff CN		Runoff in inches (Q)		Travel Time (hrs.)		Soil Group	Average Slope (%)
		Pres.	Fut.	Pres.	Fut.	Pres.	Fut.	Pres.	Fut.		
1	0.3	1.50	1.50	65	65	2.35	2.35	-	-	B	6
2	0.2	1.25	1.25	70	70	2.80	2.80	-	-	B	10
3	0.1	0.50	0.50	75	75	3.28	3.28	0.25	0.25	C	4
4	0.25	0.75	0.75	70	70	2.80	2.80	-	-	B	8
5	0.2	1.50	1.50	75	85	3.28	4.31	1.25	1.00	C	8
6	0.4	1.50	1.00	70	75	2.80	3.28	-	-	B	4
7	0.2	1.25	0.75	75	90	3.28	4.85	0.75	0.50	C	5

10 Year Frequency Storm

P = 6 inches

controlling CN at watershed outlet = 82

as an example, the final analysis may indicate a major watershed of 2000 acres with a moderate slope average, should have a constant CN of 82 which corresponds to a peak discharge of 1,701 cfs and a T_c of 2.92 hrs., while anticipated development trends and present volumes of development under construction in the sub-watersheds inflated the CN to 92 with a peak discharge of 2854 cfs and a T_c of 1.97 hrs. It is obvious some form of retention will be necessary, either in the sub-watershed or at some point between the outlet of the sub-watershed and when the peak discharge reaches the outlet of the major watershed to maintain the constant CN of 82. An example of how the whole watershed planning system, with all data available, might operate is as follows:

Black Creek watershed, with a drainage area of 960 AC (1.5 M^2) has a present CN condition of 80 which the Town Council wishes to maintain. Several developers are to develop in this watershed and it has been computed that, due to the development, the future CN for this watershed will be 85. In the same respect the time of concentration for the present conditions is 0.9 hrs. and 0.6 hrs. for the future condition. Based on P = 5.6 inches for a 24 hour 10 year frequency rainfall, determine the peak discharge for the watershed planning unit. Reference will be to the graphic method which utilizes Chart 11 (peak discharge in CSM per inch of runoff).

Present condition:

Q = 3.42 inches for CN 80 and P = 5.6 inches from Chart 3. From Chart 11, T_c = 0.9 hrs., qp = 345 CSM per inch of runoff. Therefore,

$$q = qp\ (DA)(Q) = 345\ (1.5)\ (3.42) = 1{,}769 \text{ cfs}$$

Future condition:

Q = 3.93 inches for CN 85 and P = 5.6 inches from Chart 3. From Chart 11, T_c = 0.6 hrs., qp = 460 CSM per inch of runoff.

Therefore,

$$q = qp\ (DA)(Q) = 460\ (1.5)(3.93) = 2{,}711 \text{ cfs}$$

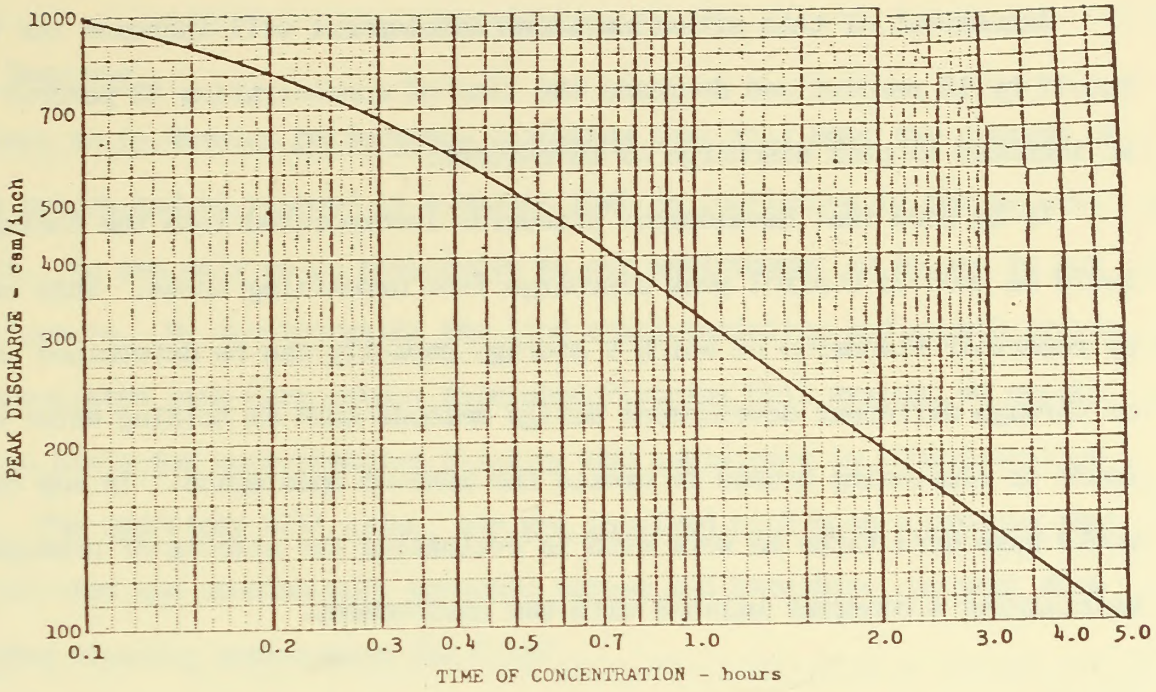


Chart 11 -- Peak discharge in csm per inch of runoff versus time of concentration (T_c) for 24-hour, type-II storm distribution.

Soil Conservation Service, Urban Hydrology for Small Watersheds, Technical Release No. 55 U. S. Department of Agriculture, Washington, D. C., 1975, page 5-5.

Assessment of this situation shows development will increase the total runoff by 15 percent and decrease the time of concentration 33 percent meaning an increase in peak discharge of 53 percent.

It is here that development standards incorporated into the Zoning Ordinance would be used to control peak discharge from urbanizing areas. This can be done by reservoir standards of which a storage capacity can be determined and designed, or through different development design methods such as holding water on building roofs or clustering houses to create the maximum open space. In any case, Cary would have hard facts to work with in evaluating the effects of urbanization and maintaining a constant balance with the environment.

CONCLUSIONS

Demand vs Response

The idea is to develop performance standards that will meet the demands of urbanizing spaces and to respond in a manner that is contiguous to the natural environment. We can only be as responsive to our environment as we are to our own intelligences. By incorporating the land characteristics and growth trends that are associated with Cary into a Watershed Planning Unit system, we create an authentic basis for comprehensive planning and assistance in administrative decisions. The questions will arise; why get involved with such a process that is so complicated and creates more economic stress and hardships, or what does the watershed planning system mean for Cary?

Let's start out by saying by no means is this publication or any phase of government in Cary advocating multi-family use or strict development controls. A greater percentage of any residential use should be devoted to single-family dwellings on wooded lots with adjacent service oriented facilities, but the citizens and Town officials alike must be aware of the consequences financially and land use wise for which there will have to be a common understanding and working effort. Where water runoff once prevailed over natural brooks, urbanization funnels runoff rapidly to downstream points. Therefore, there has to be an effort made to satisfy the difference between the natural system and urban growth to protect our remaining land resources.

We are forever trying to manipulate the environment to cover our gross miscalculations which inevitably does harm to ourselves. Here is a chance for us to show we are not negative to nature and self-centered, but flexible in our life style and compatible with the environment.

Common sense tells us there are disadvantages to contend with when it comes to implementing watershed management, but these disadvantages are the same negative

responses that beset any outreach to achieve environmental continuity. In short, they are economic involvement and questions of maintenance and legal ramifications.

Nothing is free these days and there are definite economic connotations set forth in this publication. The burden on the developer to provide retention basins or the Town to construct large holding ponds are the pressing questions that will have to be answered along with who will maintain these structures, and the legal intanglements that will have to be overcome. These are a reality of life and everything has its price. We need to ask ourselves, just how much are we willing to pay for the future preservation of our environment?

There are advantages too, just as important and maybe less apparent at first, but in the depths of time would outdistance the disadvantages and manifest greater economic rewards and meet the needs of the community.

(a) What this system can mean to the Town Council, Planning Board, Planning Department and Cary's citizens is without end. They would be able to calculate and accurately manipulate runoff so that Cary's urban development can continue without fear of hazardous conditions to Cary's own community or our neighbors inhabiting the down stream areas.

(b) The maximum flexibility will be incorporated into this system. If it can be proven by competent means that certain conditions exist that warrant changing control data for a more relaxed runoff requirement, this should be honestly induced.

(c) The amenities created and maintained just in preserving nature, is in itself most satisfying. Recreation, open space and greenways would have a better chance of survival and would become a more vivid part of our lifestyle with possible economic returns to help offset any initial expenses.

(d) Economic expenditures in the long run would be less which is due to the availability of data from the accessment of our watershed planning units and their subsequent limitation to support urbanization. We can determine the complications of development as to soils, flood areas, runoff volumes, etc., before hand, and prevent unnecessary cost to the Town via the taxpayer later.

(e) We can consider water quality also. All the impurities such as gasoline and sedimentation which enter the streams that lead to our drinking supplies, would have a chance, in retention basins, to breakdown and dissipate to nominal quantities. Where industrial waste is concerned, there would be required retention basins and water treatment standards.

(f) Finally, the most important attribute is consideration of our fellow-man. Everyone strives for economic gain, but we need to consider the rights of others, and in so doing, must consider property and life. No one seems to think much on this unless it happens to them, and they see a life's work washed away because of the vast urbanization and lack of preventative measures up stream.

In conclusion to this publication, the Planning Department has committed itself to the fact; it is not important getting the water off the site as quickly as possible, but to retard the runoff and release it at intervals which would be in close proximity to natures systematic operations. Cary is a Town that is growing rapidly, yet still has the village appeal and openness to attract many to its boundaries. To maintain this atmosphere, we must learn to live with our environment and culminate our efforts to meet nature halfway. Watershed planning provides us the means to accomplish this and enables us to realize the importance of our precious land resources.

It is anticipated this publication will be of use to you, the reader, and provide you with a better understanding of what Cary is doing to establish a more homogeneous community. We welcome any comments or criticism and would be willing to discuss in more detail, any of item of interest in this publication.

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